UMASS/AMHERST

312066005805113

SHOUT
SHARE
IT

UNIVERSITY OF MASSACHUSETTS
LIBRARY

S
73
E4
NO.405-426

DATE DUE

SEP 6 '65
OCT 21 '68
JAN 27 '69
APR 7 1976

GAYLORD
PRINTED IN U.S.A.

*5991.41
405-426

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

OCT 1 1943

Bulletin No. 405 June, 1943

NO LONGER THE PROPERTY OF
BOSTON PUBLIC LIBRARY

Agricultural Finance in Massachusetts

By Sargent Russell and A. H. Lindsey

The general impression that Massachusetts farmers are heavily burdened with debt has a tendency to increase the cost of farm loans. This study was undertaken to determine the facts regarding this financial situation.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

1038

AGRICULTURAL FINANCE IN MASSACHUSETTS

By Sargent Russell, Research Assistant, and A. H. Lindsey, Professor of Agricultural Economics

INTRODUCTION

Existing in almost all farming areas are farmers who are heavily in debt. Rather regularly some of them reach the point where the farm is foreclosed to satisfy the creditors. The difficulties of those seriously in debt become widely known and talked about. The result is an impression of widespread debt difficulty.

Another debt or credit condition receiving wide attention is high interest rate. This may take the form of higher prices for goods to be paid for in the future or actual high interest payments charged by finance companies. When a number of such cases are known, they soon appear as the general rule.

A third condition of farming is the small amount of money earned by many farmers. One reason given for this is the high cost of money borrowed by farmers. Low income is not often, however, interpreted as the reason why large debts occur on many farms. More often the credit institutions are thought to be working incorrectly.

Because of these impressions a credit problem was thought to exist in Essex County, and those in charge of farm extension work there asked for a study of rural credit. It seemed wise to extend the study to include other parts of Massachusetts also.

Objectives of the Study

This study is largely one of fact finding. The facts to be determined or the objectives are:

1. The farmer's financial standing.
2. The amount, source, purpose, and cost of credit used by farmers.
3. The adequacy of present agencies in supplying credit.
4. The factors affecting a farmer's ability to repay loans.

Another objective which is not necessarily fact finding is to suggest improvements for using credit.

Methods Used in Making the Study

A questionnaire[1] was used which the enumerator filled in from the farmer's answers. The questions on the schedule fell into three main groups.

1. *Receipts and expenses for the crop year of* 1940. Receipts included all cash taken in from sale of farm products; work off the farm; and sale of machinery, stock, land, etc. Expenses covered current and fixed cash costs for farm operation; purchases of new machinery, stock, land, buildings; and interest paid on debts.

2. *Inventory of assets and liabilities, March* 1, 1941. All farm assets were included; but cash on hand, stocks and bonds, and value of life insurance were not obtained. Liabilities and credit use covered farm business debts outstanding on March 1, 1941.

---

[1] Appendix.

3. *A brief history and description of the farm.* This included such things as date of acquisition, purchase price and mortgage, original mortgage holder, age of operator, etc.

The farmers to be interviewed were chosen in the following way:

1. Areas were chosen which, in the knowledge of those working with Massachusetts agriculture, best represented one of the following types of farming: dairy, poultry, vegetable, fruit, and tobacco and onions.
2. A representative town or towns in each area was picked.
3. As nearly as possible all commercial farmers in each of the selected towns were personally interviewed. A commercial farmer was considered one receiving 50 percent or more of his gross income from farming. The county agent not only helped to draw up the list of farmers but also aided by sending each farmer a letter announcing that an interview was to be expected.

All tabulation and analysis of the records were done by hand with only the aid of adding and calculating machines.

The periods during which records were taken covered five months, March 1 to July 31, 1941.

Reliability of the Sample

Because of the way in which the study was made and because the study is based on a sample, reliability is considered to rest on:

1. The size of the sample in order to minimize sampling error.
2. The types of farming in the sample as compared to types of farming in the State.
3. The ability of the interviewers to take survey records.[2]

The results are presented for all farms regardless of location or type; therefore, the sample is compared with totals for the State. Table 1 gives a comparison of the source of gross farm income for the study and for the State. There are discrepancies between the study and the State in proportions of income from various types of agriculture. The differences are not large and the emphasis on types is properly placed in the study. For comparable types of agriculture the sample represents 2.5 percent of the total income.

The areas from which the different types of farming were taken are shown in Table 2. The areas from which the dairy and poultry samples were taken were scattered. The onion and tobacco farms were from only one area, but this type of farming is localized and one area is sufficient. The same situation exists also for fruit farms. The vegetable areas of the State are primarily around Boston. The sample did not cover the areas to the west and south of Boston.

The proportion of farms by type in the study does not coincide with the proportion as indicated by the 1940 census. Neither of these proportions coincides with the proportion of income received from different farm enterprises (Table 1), but the proportion of farms by type in the sample is slightly more in line with the proportion of farms by type as indicated in the State income figures. Assuming that income would represent the approximate number of farms engaged in each type of farming, the comparison of farms by type with income by type of enterprise would favor the sample over the census in representing the proportions of commercial farms in the State by type.

---

[2] All records except those in Hatfield, Hampshire County, were taken by the senior author. In Hatfield, Anthony Rojko, a graduate of Massachusetts State College, took the records. His knowledge of Polish was invaluable for this purpose.

Table 1.—Comparison of Gross Cash Income on 272 Farms Surveyed with Gross Cash Income for the State as Reported by the Agricultural Marketing Service, 1940.

Source of Income	Cash Income Dollars		Percent of Total Income	
	272 Farms	State Total	272 Farms	State Total
Dairy products	560,787	24,302,000	37.7	41.1
Cows and calves sold	57,294	2,643,000	3.9	4.5
Eggs sold	270,506	9,141,000	18.2	15.5
Other poultry products	144,647	5,089,000	9.7	8.6
Turkeys, wool, hogs, sheep, and other livestock		*3,392,000 (a)		
Tobacco	99,042	2,802,000	6.6	4.7
Potatoes	14,893	1,813,000	1.0	3.1
Truck crops	220,628	9,723,000	14.8	16.5
Apples	103,183	2,213,000	6.9	3.8
Peaches	455	83,000	**	0.1
Pears	552	20,000	**	**
Strawberries	4,922	634 000	0.3	1.1
Other fruit		*4,271,000 (b)		
Other receipts	*47,796 (c)	*10,207,000 (c)		
Government payments	13,994	619,000	0.9	1.0
Outside income	*83,708 (d)			
Total	1,622,407	76,952,000		
*Non-comparable items	131,504	17,870,000		
Total comparable items	1,490,903	59,082,000	100.0	100.0

**Less than 0.05 percent.

(a) These types of farming not covered in the survey.

(b) Primarily cranberries.

(c) For the survey, other receipts were sale of machinery, etc.; for the State, they were primarily greenhouse products.

(d) No figure given for the State.

Table 2.—Types of Farming and Number of Farms Surveyed in the Areas Chosen for Study.

County	Number of Farms by Type of Farming					
	Dairy	Poultry	Vegetable	Onions and Tobacco	Fruit	Total
Essex	57	17	38		2	114
Berkshire	45	4			1	50
Plymouth	12	18				30
Worcester	24	1	1		9	35
Hampshire		1	1	41		43
Total farms						
This study	138	41	40	41	12	272
Census	7,001	5,211	1,762	2,179	2,120	18,273
Percent						
This study	50.7	15.1	14.7	15.1	4.4	100
Census	38.3	28.5	9.7	11.9	11.6	100

FARMERS' FINANCIAL POSITION

Net worth is the amount of capital owned debt free. It is that part of the capital upon which an operator may expect to earn and to retain an interest return. It also shows in part the financial strength of the operator; the larger the net worth, the greater is the operator's financial strength.

However, to the banker or creditor, the relationship of net worth to total assets is also important. This relationship, percent net worth or net worth expressed as a percent of assets, gives an idea of the amount of capital available to secure the debt.

Thus net worth can be expressed in two ways to show financial strength: (1) from the operator's point of view, the more dollars of net worth the better his position; (2) from the banker's point of view, the higher the percent net worth the better the operator's position. Both aspects are presented in Table 3.

Table 3.—Frequency Distribution by Percent Net Worth and Amount of Net Worth in Total Assets, 272 Massachusetts Farms, March 1, 1941.

Percent Net Worth	Amount of Net Worth (Dollars) 0 or less	1-3,000	3,001-6,000	6,000-9,000	9,001-12,000	12,000-15,000	15,000 & over	Total Owner-operated farms	Rented Farms	All Farms Number	All Farms Percent
					Number of Farms						
100			4	13	6	6	11	40	3	43	16
75 – 99		2	17	20	16	7	23	85	6	91	33
50 – 74		10	29	34	8	10	3	94	3	97	35
25 – 49		15	10	5				30	2	32	12
1 – 24		6						6	1	7	3
0 or less	2							2		2	1
Total farms											
Owner-operated	2	33	60	72	30	23	37	257			
Rented		10	5						15		
All	2	43	65	72	30	23	37			272	
Percent											
Owner-operated	1	13	23	28	12	9	14				100
Rented		67	33								100
All	1	16	24	26	11	8	14				100

To appraise the financial position of these farmers a standard to which their position can be compared is necessary. The average total capital used was about $12,000 and the average net worth was about $9,000. As a rule of thumb, a farmer may consider 50 percent net worth as a minimum for financial safety. On this basis 37 percent of the owner-operators did not have sufficient capital for an average farm. There were 65 percent who had less than the average dollars of net worth; but only 16 percent owned less than 50 percent of their total capital.

Within each group with approximately the same dollars of net worth, there was a range in percent net worth. Likewise there was a range in dollars of net worth for most of the groups with approximately the same percent net worth. This illustrates the necessity for considering both aspects of net worth. If such consideration is given, then a better picture of financial position can be reached. Using $6,001 net worth and 50 percent net worth as minimums for financial safety, there were 39 percent of the farmers who did not meet these minimums.

Net cash receipts were low on a large proportion of these farms (Table 4). If it can be assumed that $500 is a minimum on which a farm family should have to live, then in 1940 about 45 percent of those who owed money did not make enough to live and pay off anything on their debts. On 26 percent of the farms cash expenses were more than cash receipts. There was no relationship between income and total liabilities.

Table 4.—*Frequency Distribution of Farms by Net Cash Receipts and Total Liabilities*, 272 *Massachusetts Farms*, 1940.

Total Liabilities (Dollars)	Cash Receipts Minus Cash Expenses* (Dollars)						Total Farms		
	-501 or below	-500 to 0	1-500	501-1,000	1,001-1,500	1,501 and over	Number	Percent	Average Income (Dollars)
				Number of Farms					
0	7	3	5	8	6	14	43	16	921
1 - 1,500	5	7	17	17	9	15	70	25	1,101
1,501 - 3,000	5	10	10	12	12	11	60	22	894
3,301 - 4,500	5	4	12	5	6	8	40	15	676
4,501 - 6,000	9	4	1	5	4	10	33	12	1,388
6,001 - 7,500	5	1	1	3	1	2	13	5	68
7,501 and over	2	3	1	1	1	5	13	5	1,208
Total Farms									
Number	38	32	47	51	39	65	272		
Percent	14	12	17	19	14	24		100	
Average income	-$1,193	-$171	$248	$714	$1,229	$3,300			$955

*See section on Method of Study for definition of Cash Receipts and Cash Expenses.

There are several methods of measuring income. Two others used here are: labor income, which attempts to show what the operator received simply for his labor; and cash receipts minus current cash expenses, which is net cash receipts excluding expense for new machinery and permanent improvements. A comparison of these methods of measuring income is shown in Table 5.

Table 5.—*Comparison of the Distribution of Farms by Three Methods of Measuring Income*, 272 *Massachusetts Farms*, 1940.

Method of Measuring Income	Size of Income (Dollars)						Average Income
	-501 or below	-500 to 0	1-500	501-1,000	1,001-1,500	1,501 and over	
			Number of Farms				*Dollars*
Net cash receipts	38	32	47	51	39	65	955
Net cash receipts excluding cost of new machinery and permanent improvements	17	25	52	48	34	96	1,381
Labor income	61	52	53	36	26	44	459
			Percent of farms				*Percent*
Method 1	14	12	17	19	14	24	100
Method 2	6	9	19	18	13	35	100
Method 3	22	19	20	13	10	16	100

Again assuming $500 to be a minimum which a farm family should have to meet cash living expenses, low income appears to be a characteristic of from 34 to 61 percent of the farms.

To measure the success which farmers have had in buliding up their capital in the farm, a comparison should be made between net worth in total assets when the farm was acquired and net worth in total assets when the survey was taken. However, the only figure obtainable for net worth at the time the farm was acquired was net worth in land and buildings, and even this was limited to purchased farms since it was difficult to get those who inherited the farm to put a price on the land and buildings when they inherited the farm. Therefore the change in net worth in land and buildings is given in Table 6 for purchased farms only, to show what success farmers have had in building up their capital and how long they have been operating.

Table 6.—Frequency Distribution of Purchased Farms to Show Change in Net Worth of Land and Buildings while Present Operator has been on the Farm, 177 *Massachusetts Farms,* 1940.

Years Present Operator on Farm	Change in Net Worth (Dollars) Decrease	Change in Net Worth (Dollars) Increase 0-1,500	Increase 1,501-3,000	Increase 3,001 and over	Total Farms	Average (Dollars) Decrease in Mortgage	Average (Dollars) Increase in Price of Land and Buildings	Average (Dollars) Change in Net Worth
			Number of Farms					
1 – 5	3	9	4	6	22	–333	2,366	2,033
6 – 10	2	4	4	5	15	404	3,005	3,409
11 – 15	8	12	5	9	34	575	1,068	1,643
16 – 20	8	7	12	8	35	556	1,322	1,878
21 – 25	5	7	6	8	26	282	2,145	2,427
26 – 30	1	2	4	9	16	–1,820	5,894	4,074
31 – 35		2	4	7	13	–233	4,008	3,775
36 and over		1	3	12	16	470	5,925	6,395
Total farms	27	44	42	64	177			
Average—								
Decrease in mortgage	–$715	$489	$214	$446		$116		
Increase in price of land and buildings	–1,672	524	2,032	6,444			$2,687	
Change in net worth	–2,387	1,013	2,246	6,890				$2,803

The range in change in net worth over the last 30 years (since 1911) is great. The decreases in net worth were greatest for those farmers who acquired a farm 11 to 25 years ago (1916 to 1930). A possible explanation of this may be the high price paid for farms during this period. However, some of the farmers who acquired farms during this same period have been among the leaders in increasing net worth. About 15 percent of the purchased farms show a decrease in net worth, most of which has been due to a lowering of the price of the land and buildings, although mortgages have also increased. The greatest increase in net worth, in most cases, has been in the price of land and buildings. Paying off mortgage indebtedness has been a relatively unimportant method of increasing net worth in land and buildings.

There are two ways of changing net worth: paying off the debt or increasing the asset. Table 7 shows the change in net worth on the basis of the way in which the change was made. The average annual change for each farm has been used.

There were 68 percent of the farmers who indicated that the price of the farm had increased during the period he had operated it. Practically all of these had an increase in net worth. On 19 percent of the farms the price of the land and buildings was indicated as decreasing. Two-thirds of these farms showed a decrease in net worth.

About half of the farmers had paid off something on mortgages. The others are divided about 30 percent and 20 percent between increasing the mortgage and no change. The proportion of farms which decreased in net worth in the three mortgage-change groups was about the same. However, the tendency was for net worth to increase more if payment had been made on the mortgage.

Table 7.—Frequency Distribution of Purchased Farms Showing Average Annual Change in Net Worth and Way in Which Change Came About on 177 Massachusetts Farms.

Reason for Change in Net Worth	Annual Change in Net Worth (Dollars)				Total Farms		Average Increase in Net Worth (Dollars)
	Decrease	Increase			Number	Percent	
		0-100	101-201	201 and over			
	Number of Farms						
Increase in price of land and buildings							
Decrease in mortgage		11	12	27	50	28	439
No change in mortgage		7 (a)	9 (b)	12 (b)	28	16	413
Increase in mortgage	2	18	9	14	43	24	206
No change in price of land and buildings							
Decrease in mortgage		4	2	5	11	6	191
No change in mortgage		8 (b)			8	5	0
Increase in mortgage	3				3	2	−87
Decrease in price of land and buildings							
Decrease in mortgage	12	9	3		24	14	−67
No change in mortgage	6 (c)				6	3	−101
Increase in mortgage	4				4	2	−195
Total farms							
Number	27	57	35	58	177		
Percent	15	32	20	33		100	
Average increase in net worth							$233

(a) 4 farms not mortgaged at time either of purchase or of interview.
(b) 3 farms not mortgaged at time either of purchase or of interview.
(c) 1 farm not mortgaged at time either of purchase or of interview.

If it is assumed that a farmer starts out with a 50 percent debt and in 30 years is going to own free and clear an average farm which will be valued at $9,000, then less than half of these farmers would make it, since $150 a year would be required.

Table 8 shows a frequency distribution of the prices paid for farms during three periods. Over 80 percent of the farms priced at more than $9,000 when acquired were purchased during the period 1916 – 1930. The proportion of higher priced farms, 20 percent, was greater during this period than during any other.

Table 8.—Frequency Distribution of Purchase Price of 177 Massachusetts Farms, by Periods When Farms Were Aacquired.

Purchase Price (Dollars)	Period When Farm Was Acquired							
	1931-40	1916-30	Before 1916	Total	1931-40	1916-30	Before 1916	Total
	Number of Farms				*Percent of Farms*			
1 – 3,000	11	26	25	62	30	27	56	35
3,001 – 6,000	16	33	13	62	43	35	29	35
6,001 – 9,000	8	17	5	30	21	18	11	17
9,001 – 12,000	1	11	1	13	3	12	2	7
12,001 and over	1	8	1	10	3	8	2	6
Total	37	95	45	177	100	100	100	100

Table 9 shows the degree of success which farmers have had in increasing their net worth.

Table 9.—Frequency Distribution of 177 *Purchased Farms by the Amount Paid for Farm and Average Annual Change in Net Worth, Massachusetts.*

Purchase Price of Farm (Dollars)	Average Annual Change in Net Worth (Dollars)				Total	Average		
	Decrease	Increase				Decrease in Mortgage	Increase in Price of Land and Buildings	Present Percent Net Worth
		0-100	101-200	201- and over				
		Number of Farms						
1 – 3,000	6	24	13	19	62	$–614	$4,483	75
3,001 – 6,000	6	19	16	21	62	251	2,889	68
6,001 – 9,000	4	7	5	14	30	976	1,712	61
9,001 – 12,000	4	5	1	3	13	2,478	–1,485	67
12,001 and over	7	2		1	10	–1,855*	–1,345*	36*
Total or average	27	57	35	58	177	$116	$2,687	67
		Percent of Farms						
1 – 3,000	10	39	21	30	100			
3,001 – 6,000	10	30	26	34	100			
6,001 – 9,000	13	23	17	47	100			
9,001 – 12,000	31	38	8	23	100			
12,001 and over	70	20		10	100			
Total	15	32	20	33	100			

*With one farm omitted, averages are: Decrease in mortgage +$1,039; Increase in price of land and buildings $-2,994; Net worth 50 percent.

The proportion of farms showing a decrease in net worth was greater for the higher-priced farms (over $9,000). This, combined with the fact that most of the higher-priced farms were purchased during the period 1916-30, may explain why a greater proportion of the farms purchased during this period failed to increase their net worth.

The three factors, percent net worth, income, and change in net worth, may now be combined into one analysis. For this analysis the following points are used to indicate an unfavorable position: (1) percent net worth, 49 percent or less; (2) income, $500 or less; (3) net worth since acquiring farm, unchanged or decreased. Table 10 shows the results by this classification for 177 purchased farms for which all the information is available.

The distribution of farms under this triple sort would appear theoretically to give a good picture of the financial standing of these farmers. However, upon further examination, other factors which complicate the picture are found. For instance, the net worth of some farmers has decreased because of a drop in prices, but they have been able to stand the fall and are still in good standing. Some farmers manage to increase net worth by living very frugally. Difference in size of family, also alters the purpose for which the farm income will be spent. Financial standing is raised on some farms through income earned by members of the family working outside. Where the farmer is just getting started on the farm, the net worth is apt to be low.

These qualifications may lead one to believe that the above analyses have not given any better understanding of the financial position of this group of farmers. However, these conclusions, which are related to the purpose of the study, do seem justified.

1. The proportion of farmers who had a dangerously high debt load or poor financial condition was not over 20 percent.

2. Low income from farming operations was an important problem, but was not related to large debts.

3. The proportion of farmers who did not maintain or build up net worth while on the farm was not over 20 per cent.

Table 10.—*Frequency Distribution of* 177 *Purchased Farms by Three Measures of Financial Standing*, 1941.

Measures of Financial Standing	Number of Farms	Percent of Farms	Average: Annual Change in Net Worth (Dollars)	Average: Percent* Net Worth (in total assets)	Average: Net Cash Receipts (Dollars)
Net worth increased					
Net worth 50 percent or more					
Net cash receipts $501 or over....	73	41	320	79	2,136
Net cash receipts $500 or less.....	47	27	260	75	-407
Net worth 49 percent or less					
Net cash receipts $501 or over....	9	5	138	43	1,457
Net cash receipts $500 or less.....	10	6	852	37	-260
Net worth unchanged or decreased					
Net worth 50 percent or more					
Net cash receipts $501 or over....	11	6	-28	67	1,549
Net cash receipts $500 or less.....	13	7	-150	71	-372
Net worth 49 percent or less					
Net cash receipts $501 or over....	5	3	-107	19	2,138
Net cash receipts $500 or less.....	9	5	-155	22	-410
Total or average.............	177	100	$233	68	$941

*Unweighted

CREDIT USED BY FARMERS

As was mentioned in the introduction, the amount of credit being used was determined by an inventory of credit outstanding March 1, 1941. For purposes of analysis the following types of credit were recognized: (1) mortgages on real estate, (2) notes (may or may not be written in conjunction with a chattel mortgage), (3) merchant open accounts, (4) taxes past due, (5) mortgage interest and/or principal payments past due, and (6) loans from life insurance companies secured by life insurance policies.

The credit which was being used on the farms in this study will be presented in the following ways: the proportion of farmers using each type; the amount used per farmer; the sources supplying the credit; the purposes for which the farmer borrowed the money; a cross classification of sources and reasons for borrowing; the length of time the credit has been outstanding; and any other information which seems pertinent to the particular type of credit.

Real estate mortgages accounted for 78 percent of the debt on these farms (Table 11). The remainder of the debts was accounted for primarily by notes and open accounts. Taxes past due, interest and payments on the mortgage unpaid, and life insurance loans together amounted to only 3 percent of the total debt.

The total debt averaged $3,271 for all farms. This was equivalent to 25 percent of the assets, leaving a net worth in assets of 75 percent. The average mortgage debt for all farms, $2,545, was 27 percent of the owner's estimates of the price of his land and buildings. Thus net worth in land and buildings was 73 percent.

Table 11.—*Balance Sheet of* 257 *Owner-Operated Farms, Massachusetts, March* 1, 1941.

Assets	Total Value	Average per Farm	Liabilities and Net Worth	Farms Using	Total Amounts	Average for All Farms	Percent of Total Assets	Percent of Total Liabilities
Land and buildings			Mortgages	177	$654,228	$2,545	19.7	77.9
(Assessed)	($1,608,750)	($6,259)	Notes	97	106,361	414	3.2	12.6
Owner's estimate	$2,387,355	$9,290	Open accounts	120	53,952	210	1.6	6.4
Dairy livestock	337,387	1,313	Taxes	58	12,608	49	0.4	1.5
Poultry	80,581	313	Mortgage interest and principal	20	4,283	17	0.1	0.5
Horses	44,090	172	Life insurance loans	16	9,150	36	0.3	1.1
Other livestock	2,239	9						
Tractors	50,650	197	Total Liabilities		$840,582	$3,271	25.3	100.0
Trucks	55,011	214						
Autos	53,607	208	Net Worth		2,476,595	9,636	74.7	
Other machinery and equipment	201,499	784						
Feed and supplies	39,575	154						
Produce for sale	14,479	56						
Notes and accounts receivable	50,704	197						
Total Assets	$3,317,177	$12,907	Total Liabilities and Net Worth		$3,317,177	$12,907	100.0	

There were 40 farms, or 16 percent, which had no outstanding debts. There was only one farm that had outstanding debts of all six types. The percentages of farms having various combinations of types of debt are shown in Table 12.

Table 12.—*Percent of Farms with Different Types of Indebtedness, 257 Owner-Operated Farms, Massachusetts, March* 1, 1941.

	Mortgaged				Not Mortgaged				
	Notes		No Notes		Notes		No Notes		Total
	Open Accounts		Open Accounts		Open Accounts		Open Accounts		
	Yes	No	Yes	No	Yes	No	Yes	No	
Taxes past due									
Mortgage payments past due									
Life insurance loans......	0.4								0.4
No life insurance loans ...	3.1	1.2	0.4	1.2					5.9
Mortgage payments paid									
Life insurance loans......	0.4		0.4				0.4		1.2
No life insurance loans....	5.4	3.1	2.3	1.6	0.4	0.8	0.4	1.2	15.2
Taxes Paid									
Mortgage payments past due									
Life insurance loans......	0.8								0.8
No life insurance loans....	0.4	0.4							0.8
Mortgage payments paid									
Life insurance loans......	1.5	0.8		0.4	0.4			0.8	3.9
No life insurance loans....	9.0	4.3	14.4	17.5	1.2	4.3	5.5	15.6	71.8
Total.............	21.0	9.8	17.5	20.7	2.0	5.1	6.3	17.6	100.0

MORTGAGES

As has been pointed out, mortgages were the most important type of credit used by farmers as measured by dollar amounts. The mortgages discussed here are only real estate mortgages secured by a lien on the land and buildings owned by the operator.

Table 13.—*Comparison of Proportion of Owner-Operated Farms Mortgaged in Massachusetts, According to Various Sources.*

	Percent Owner-Operated Farms Mortgaged				
County	This Study 257 Farms	1940 Census	1940 Census Revised (1)	Study of 339 Farms 1934 (2)	Land Tenure Study (3)
Berkshire.........	50.0	45.6	50.0		72
Essex............	71.2	49.4	53.2		44
Hampshire........	87.8	62.3	63.8	73.3 (4)	71
Plymouth........	79.3	47.4	48.2	65.6 (5)	58
Worcester........	57.1	52.3	56.3		48
The State........	68.9	52.0	54.7	72.2	55

(1) The Census reports proportion mortgaged on the basis of total owner-operated farms. However, there is no report on mortgage for part of the farms. If these farms are removed from the total number of owner-operated farms, the revised figures result.

(2) Donley, J. E. "Study of Rural Credit in Certain Areas in Massachusetts," 1935. Largest proportion of records was taken in Connecticut Valley.

(3) Data to be published from land tenure study made by Dr. A. H. Lindsey and Edward Collins in 1941. Mail questionnaire used in gathering data.

(4) 232 farms in Connecticut Valley of Massachusetts.

(5) 32 farms Plymouth-Norfolk counties.

The proportion of mortgaged farms in the study differs from the proportion reported by the census and others (Table 13), but the reason or reasons for this difference could not be determined from available data. Investigation into some of the possible reasons showed the following:

1. Since the census includes part-time farms, the possibility that the conditions on these farms might influence the results was considered. However, a study of 180 owner-operated part-time farms in the Lowell and Taunton areas in 1929, by Dr. David Rozman, showed 68 percent of them mortgaged.

2. Since the census shows by its distribution of gross income on farms that it includes many small farms, the proportion of small farms mortgaged might explain some variation. Sorted for size on total productive man-work units, this study shows that 73 percent of the farms up to 300 productive man-work units in size were mortgaged; while of the farms of over 700 productive man-work units, 63 percent were mortgaged.

3. High value of farm land per acre might explain some of the difference. Dr. Rozman, in his bulletin "Interrelationships of Land Uses in Rural Massachusetts," classified towns of less than 10,000 population in three groups on the basis of assessed value per acre of farm land. Using this classification, the proportion of mortgaging shown by this study was 62 percent in low-value towns, 60 percent in medium-value towns, and 73 percent in high-value towns.

4. On the basis of type of farming, this study shows that 66 percent of dairy, 70 percent of poultry, 80 percent of vegetable, 73 percent of fruit, 100 percent of onion, and 81 percent of tobacco farms were mortgaged.

5. A factor which might explain the variation is method of farm acquisition. This study shows 41 percent of inherited farms mortgaged, compared to 81 percent of purchased farms. A study made by Dr. A. H. Lindsey shows 42 percent of inherited and 59 percent of purchased farms mortgaged. In this study 28 percent of the farms were inherited; in Dr. Lindsey's study, 30 percent.

6. Rich men's farms might also influence census data.

The following conclusions appear to be justified: (1) More than half of the farms in the State are mortgaged; but for commercial farmers depending on farming for a living, the proportion mortgaged is probably nearer 65 percent than 50. (2) The proportion of farms mortgaged is higher in the Connecticut Valley than in the rest of the State.

The amount of mortgages per farm varies from $100 to $44,000. About a third of the mortgages outstanding were from $1,501, to $3,000 (Table 14). Although only 41 percent of the farms were mortgaged for more than $3,000, these 41 percent were carrying 69 percent of the mortgage debt. The 9 percent of the farms with the largest mortgages owed 32 percent of all the mortgage debt.

Table 14.—*Frequency Distribution of Amount of Mortgage Outstanding on Farms and Proportion of Total Mortgage in Each Size Group,* 177 *Massachusetts Farms.*

Total Mortgage per Farm (Dollars)	Farms		Mortgages Outstanding	
	Number	Percent	Total Amount	Percent of Total
1,500 and under	37	21	$37,795	6
1,501 – 3,000	67	38	160,974	25
3,001 – 4,500	30	17	112,595	17
4,501 – 6,000	26	15	133,345	20
6,001 – 44,000	17	9	209,519	32
Total	177	100	$654,228	100
Average per farm			3,696	

The distribution of the dollar amount of outstanding mortgage per farm (shown in Table 14) may not be representative of the State, as indicated by the great variation in average size of outstanding mortgage per farm reported from different sources (Table 15).

Table 15.—*Average Size of Mortgage Indebtedness for Massachusetts, as Reported by Different Sources.*

Source Reporting Average Size of Mortgage Outstanding		Date for Report	Average Amount of Mortgage per Mortgaged Farm
Census of Agriculture (1)		4/1/40	$2,470
Bureau of Agricultural Economics (2)		1/1/35	2,727
Survey 257 Owner-Operated Farms (this study)		3/1/41	3,696
Survey 333 Owner-Operated Farms (3)		1934	4,853
Farm Credit Administration Mortgages			
F. C. A.	Federal Land Bank (4)	1/1/41	$2,205
	Land Bank Commissioner (5)	1/1/41	1,656
Survey 257 Farms (this study)			
	Federal Land Bank	3/1/41	3,400
	Land Bank Commissioner	3/1/41	2,091
Survey 333 Farms			
	Federal Land Bank (3)	1934	4,575

(1) 16th Census of United States, 1940. According to the Census, the total amount of mortgages reported for Massachusetts, April 1, 1940, was $37,359,000.

(2) Agricultural Statistics, 1941, p. 593. The total amount of mortgages reported for Massachusetts, January 1, 1940, was $54,497,000.

(3) Donley, J. E. Thesis, "Study of Rural Credit in Certain Areas in Massachusetts," 1935.

(4) Agricultural Statistics, 1941, p. 598.

(5) Ibid., p. 604.

The average size of mortgage indicated by surveys runs consistently higher than the average size reported by those agencies which report for the entire State. The average size of mortgage found in this study was about 50 percent higher than that reported by other agencies. This may be the difference between full-time commercial farms, which the surveys cover, and all farms, including part-time farms, which State-wide reports cover.

There were 3,093 Federal Land Bank loans reported by the Farm Credit Administration in Massachusetts, and 2,276 Land Bank Commissioner loans. The total outstanding on these two types of mortgages was $10,588,468. Assuming that most of this debt was outstanding on 3,093 farms with Federal Land Bank loans, the average mortgage indebtedness of these farms would be $3,423. This figure compares closely with $3,696, which was the average mortgage indebtedness found by this study for all farms. However, if figured the same way (i. e., adding Federal Land Bank and Land Bank Commissioner loans together and dividing by Federal Land Bank borrowers), the average mortgage for the farms in this study was $4,504.

A frequency distribution of the mortgages on the survey farms when they were purchased shows a distribution which is approximately the same as for the present outstanding mortgage (Table 16).

Except for the last ten-year period, over half the mortgages were for no more than $3,000. There was slight indication that the size of mortgage was increasing. Thus not only were over 50 percent of the mortgages outstanding on farms no more than $3,000, but also over 50 percent of the original mortgages were no more than $3,000. The average size of mortgage was between $3,000 and $4,000.

Table 16.—*Frequency Distribution of Total Mortgage at Time Farms Were Purchased, by Periods,* 151 *Massachusetts Farms.*

Size of Mortgage at Time of Purchase (Dollars)	Period When Farm Was Purchased				Total or Average	Period When Purchased				Total
	1931-1940	1921-1930	1911-1920	Before 1911		1931-1940	1921-1930	1911-1920	Before 1911	
	Number of Farms					*Percent of Farms*				
1 – 1500	4	14	7	9	34	12	23	21	37	23
1,501 – 3,000	11	21	11	10	53	32	36	34	42	35
3,001 – 4,500	9	11	7	5	32	26	18	21	21	21
4,501 – 5,000	3	9			12	9	15			8
6,001 and over	7	5	8		20	21	8	24		13
Total	34	60	33	24	151	100	100	100	100	100
Average Mortgage	$3,875	$3,360	$3,792	$2,017	$3,357					

There were 88 percent of those with mortgages up to $3,000 that had a net worth of 50 percent or more in land and buildings; but only 55 percent of those with larger mortgages were in this category.

The sources from which farmers borrowed for their mortgages when purchasing the farm are shown in Table 17. Previous to 1911 individuals were the major source of borrowing for mortgages. Since that time banks, primarily savings banks, have supplied the largest proportion of farmers with funds to buy farms. The Federal Land Bank and Land Bank Commissioner have been growing in importance.

Table 17.—*Frequency Distribution of Mortgages, Showing Source of Borrowing at Different Periods when Farm was Purchased,* 151 *Massachusetts Farms.*

Source of Borrowing	Period When Purchased				Total	Period When Purchased				Total
	1931-1940	1921-1930	1911-1920	Before 1911		1931-1940	1921-1930	1911-1920	Before 1911	
	Number of Farms					*Percent of Farms*				
Banks	15	36	18	9	78	44	60	55	38	52
Individuals	9	16	8	13	46	26	26	24	54	30
Federal Land Bank and Land Bank Commissioner	7	3			10	21	5			7
Cooperative banks	2	4	4	1	11	6	7	12	4	7
Others	1	1	3	1	6	3	2	9	4	4
Totals	34	60	33	24	151	100	100	100	100	100

The mortgages outstanding by sources at the time the survey was taken are shown in Table 18. The four principal sources of mortgages were banks 40 percent, Federal Land Bank 27 percent, individuals 17 percent, and Land Bank Commissioner 9 percent. "Others" accounted for only 7 percent. This indicates that a considerable shift has taken place in the source of mortgaging since the time when the farms were first mortgaged. State reports indicate that the Federal Land Bank and Land Bank Commissioner have only 19 percent of the total mortgages outstanding in the State; but even this would indicate a large amount of shifting if the original loaning agencies shown by this study were used as an indication.

Table 18.—*Frequency Distribution of Farms by Source and Size of Total Mortgage Outstanding*, 177 *Massachusetts Farms*, 1941.

Source of Mortgage	Mortgages Outstanding[1] Number	Total Amount (Dollars)	Percent of Total	Amount per Farm (Dollars)
Banks	84	246,424	38	2,934
Individuals	38	112,785	17	2,968
Federal Land Bank	53	180,173	27	3,400
Land Bank Commissioner	28	58,556	9	2,091
Cooperative Banks	10	12,315	2	1,232
Others	13	43,975	7	3,383
Totals		$654,228	100	

[1] According to Agricultural Finance Review, Vol. 4, No. 2, November 1941, the total outstanding mortgages in the State amounted to $55,120,000, of which $1,304,000 or 2.4 percent was held by insured commercial banks, and $10,588,000 or 19.2 percent by the Federal Land Bank and Land Bank Commissioner.

Three-fourths of the mortgaged farms had only one first mortgage; 3 percent of the farms had two first mortgages[3] either with or without second or third mortgages; 18 percent of the mortgaged farms had second mortgages. Table 19 shows the source of mortgage credit but indicates the combination of loaning agencies used by the farmers.

Table 19.—*Source of Mortgages on* 177 *Mortgaged Farms in Massachusetts.*

Source of Mortgage	Number of Farms	Percent of Farms
Banks	69	39
Individuals	26	15
Federal Land Bank	22	12
Cooperative Bank	9	5
Federal Land Bank and Land Bank Commissioner	21	12
Other Sources or Combinations		
One (1)	4	2
Two (2)	16	9
Three (3)	8	5
Four (4)	2	1
Total	177	100

(1) Charity Association, 2; H. O. L. C., 1; Private Corporation, 1.

(2) Two Banks, 7; Bank and Individual, 3; Private Corporation and Individual, 2; Farm Security Administration and Individual, 1; Cooperative Bank and Individual, 1; Bank and Federal Land Bank, 1; Federal Land Bank and Lotta Crabtree, 1.

(3) F. L. B. and L. B. C. and Disaster Loan Corporation, 2; F. L. B., L. B. C., and Bank, 2; F. L. B., L. B. C., and Individual, 1; F. L. B. and two Individuals, 1; Insurance Company and two Individuals, 1; two Banks and Individual, 1.

(4) F. L. B., L. B. C., Disaster Loan Corporation, and Individual, 1; F. L. B., L. B. C., Bank, and Lotta Crabtree, 1.

The Farm Credit Administration through the Federal Land Bank and Land Bank Commissioner was serving 30 percent of the farmers and held 36 percent of the mortgage debt. Individuals served 20 percent of the borrowers and held 17 percent of the mortgage debt. "Others" served 6 percent of the borrowers and held 7 percent of the mortgage debt. The service to borrowers by sources totals more than 100 percent since some borrowers used more than one source.

---

[3] Two first mortgages on the same farm were made possible by mortgaging different parts of the farm owned by one farmer.

The primary purpose or reason for a mortgage is to make possible the purchase of a farm; 116 or two-thirds of the mortgages were for this purpose (Table 20). It is often cheaper to construct or repair buildings on long-term mortgage credit than on short-term; 5 percent of the mortgages were of this type. Twenty-seven percent of the mortgages were for refinancing of debt. Of these, 6 percent were clearly for the consolidation of small current indebtedness under a mortgage; the other 21 percent originated primarily in the refinancing of purchase mortgages, but undoubtedly many of these represented the consolidation of current indebtedness with the original mortgage debt, under the new mortgage. Sixty-six percent of the refinance mortgages were over $3,000, while only 38 percent of the mortgages for the purchase of real estate were over $3,000.

Table 20.—Frequency Distribution of Farms Showing Reason for Present Mortgage by Size of Total Mortgage, 177 *Massachusetts Farms*, 1941.

Size of Total Mortgage (Dollars)	Reason for Mortgage					Total
	Buy Real Estate	Refinance Mortgage	Finance Debts	Building and Repair	Unknown	
	Number of Farms					
1 – 1,500	20	3	8	3	3	37
1,501 – 3,000	52	10	1	3	1	67
3,001 – 4,500	17	11		2		30
4,501 – 6,000	16	8	1	1		26
6,001 and over	11	6				17
Total Farms						
Number	116	38	10	9	4	177
Percent	66	21	6	5	2	100

Table 21.—Frequency Distribution of Farms by Sources and Reason for Mortgage Outstanding, 177 *Massachusetts Farms*, 1941.

Source of Mortgage	Reason for Mortgage					Total
	Buy Real Estate	Refinance Mortgage	Finance Debts	Building and Repair	Unknown	
	Number of Farms					
Banks	62	2	3	2	1	70
Individuals	18	1	4	2	1	26
Federal Land Bank	6	13	1	2		22
Cooperative Banks	3	1	1	2	2	9
Federal Land Bank and Land Bank Commissioner	6	15				21
Others	21	6	1	1		29
Total	116	38	10	9	4	177
	Percent of Farms					
Banks	89	3	4	3	1	100
Individuals	69	4	15	8	4	100
Federal Land Bank	27	59	5	9		100
Cooperative Banks	34	11	11	22	22	100
Federal Land Bank and Land Bank Commissioner	29	71				100
Others	73	21	3	3		100
Total	66	21	6	5	2	100

The agencies which held the mortgages made for various purposes are shown in Table 21. Except for the Federal Land Bank and Land Bank Commissioner, most of the business done by others taking mortgages was done for purchase of real estate. Refinancing old mortgages was the primary activity indicated for the Federal Land Bank and Land Bank Commissioner. The figures reported for purpose of Federal Land Bank loans were similar to those reported by Farm Credit Administration which showed that 64 percent of the amount loaned in 1939 and 1940 was for refinancing indebtedness, 20 percent for purchase of land and redemption from foreclosure, 10 percent for general agricultural uses including building and improvement, 5 percent for purchase of stock, and 1 percent for fees.[4]

The age of mortgages which were outstanding is shown in Table 22. About 70 percent of the mortgage contracts and the amount of mortgage outstanding was not over 15 years old; less than 5 percent was over 30 years old. These percentages do not give a true picture, however, for on many farms the mortgages had been refinanced, while on others new mortgages had been taken out after the original mortgage had been paid off.

---

[4] Agricultural Statistics, 1940, 1941.

Table 22.—Frequency Distribution of all Mortgage Contracts by Age Groups, 177 *Massachusetts Farms,* 1941.

Age of Mortgage Contracts Outstanding (Years)	Contracts		Original Amount of Mortgages (Dollars)	Present Mortgages		Percent Present of Original Amount
	Number	Percent of Total		Amount (Dollars)	Percent of Total	
1 – 5	76	34	224,700	206,810	35	92
6 – 10	46	21	130,500	99,730	17	76
11 – 15	39	17	125,950	98,222	17	78
16 – 20	28	12	87,500	68,060	12	78
21 – 25	16	7	62,550	61,943	10	99
26 – 30	11	5	41,560	35,660	6	86
31 – 35	7	3	13,600	12,500	2	92
36 and over	3	1	7,500	6,500	1	87
Total	226	100	693,860	589,425	100	85
Unknown	10			$64,703		

Table 23.—Frequency Distribution of Farms by Periods When Acquired, Showing Mortgage Status When Acquired and on March 1, 1941, 257 *Owner-Operated Massachusetts Farms.*

Mortgage Status	Period When Present Operator Acquired Farm				Total
	1931-40	1921-30	1911-20	Before 1911	
			Number of Farms		
No mortgage at start					
None now.	10	14	15	10	49
Mortgaged now.	5	7	7	4	23
Mortgaged at start					
None now (paid off). .	2	7	9	13	31
Mortgaged now.	41	61	33	19	154
Total farms.	58	89	64	46	257

A common policy used today by many mortgage holders is to pay off a part of the mortgage principal regularly so that in time the farm will be mortgage free. Of the farmers in this study who started with a mortgage, 40 percent were mortgage free after 30 years. However, this proportion of farms which became mortgage-free is high if consideration is given to all farms (Table 23).

Of the 46 farms which the present operator had acquired over 30 years ago, 32 were mortgaged when the operator acquired the farm. At the time of the survey 23 were mortgaged. Thus there was a net decrease of 9, or 28 percent, in the number of mortgaged farms which had been operated by the same farmers over 30 years.

Table 24.—Frequency Distribution of Farms Showing Dollar Change in Mortgage Between Time When Farm Was Acquired and March 1, 1941, 208 *Massachusetts Farms.*

Amount Change in Mortgage (Dollars)	Period When Present Operator Acquired Farm				Total
	1931-40	1921-30	1911-20	Before 1911	
	Number of Farms				
Increase					
3,001 or more	4	2	4	5	15
1,501 – 3,000	3	5	3	2	13
1 – 1,500	5	14	13	3	35
No Change	12	14	5	2	33
Decrease					
1 – 1,500	16	21	11	12	60
1,501 – 3,000	3	8	2	5	18
3,001 or more	2	8	5	3	18
Unknown	3	3	6	4	16
Total farms	48	75	49	36	208

Table 25.—Total Amount of Mortgage at Time Farm Was Acquired and on March 1, 1941, 192 *Farms Acquired During Different Periods.*

	Period When Present Operator Acquired Farm				Total
	1931-40	1921-30	1911-20	Before 1911	
Number of farms	45	72	43	32	192
Total mortgage when acquired	$163,400	$235,050	$132,900	$86,150	$617,500
Total mortgage March 1, 1941	$169,528	$232,611	$161,129	$50,802	$614,070
Net change	$+6,128	$−2,439	$+28,229	$−35,348	$−3,430
Percent present of original amount	104	99	121	59	99
Number of farms increasing mortgage	12	21	20	10	63
Amount of increase	$29,533	$73,536	$66,469	$26,952	$196,490
Number of farms decreasing mortgage	21	37	18	20	96
Amount of decrease	$23,405	$75,975	$38,240	$62,300	$199,920

A comparison of the amount of mortgage at the time the farm was acquired and when the survey was taken is shown in Tables 24 and 25. Half of the farmers who indicated that they had mortgages either when they acquired a farm or when the survey was taken had paid off something on the principal since acquiring the farm. A third had increased the amount of mortgage. The others had the same amount of mortgage at both times. The experience of these farmers indicated that —

1. Of the farms which were mortgaged when acquired, 40 percent were debt-free after more than 30 years of operation by one operator; but there was only a 28 percent decrease in the proportion of farms mortgaged.

2. A relatively small proportion of farmers paid off more than $3,000 on the principal of the mortgage.

3. Half of the farmers who had mortgage experience as indicated by this study either paid nothing on or increased the principal of the mortgage.

4. For all farms as a group, regardless of time of purchase, the total amount of mortgage was just about the same when acquired and when the survey was taken.

Summary of Mortgages

1. *Proportion of farms mortgaged.* The safest answer and the one which has most popular acceptance based upon statistics shown is that slightly over 50 percent of all farms in Massachusetts were mortgaged in 1940. This survey, however, indicates that about 65 percent of the commercial farms in Massachusetts were mortgaged in 1940.

2. *Amount of mortgage per farm.* The amount outstanding varied from $100 to $44,000. Fifty-nine percent of the farms had mortgages of $3,000 or less. The average amount per farm was $3,696 which is about 50 percent higher than that reported by the census or Bureau of Agricultural Economics.

3. *Sources of mortgage credit.* In this study 40 percent of the amount of mortgage outstanding was held by banks, 27 percent by the Federal Land Bank, 9 percent by Land Bank Commissioner, 17 percent by individuals, and 7 percent by other agencies. State reports showed 19.2 percent held by Federal Land Bank and Land Bank Commissioner on January 1, 1941.

4. *Purpose of mortgage credit.* Sixty-six percent of the mortgages were for purchase of real estate, 21 percent for refinancing mortgages, 6 percent for financing other debts, 5 percent for building and building repair, and 2 percent unknown.

5. *Purpose of mortgages by sources.* Banks and individuals made most of their loans for purchase of real estate. Federal Land Bank and Land Bank Commissioner loans were made primarily to refinance other mortgages.

6. *Age of mortgage contracts.* Seventy-two percent of the mortgages were less than 16 years old. This does not indicate the proportion of farms that have been mortgaged for this length of time, however.

7. *Payments on the principal of mortgages.* These have not been large. Less than half the farms operated by the same operator for 30 years have become mortgage free.

OTHER CREDIT

In the discussion of real estate mortgages the number of farms was restricted to the 257 owner-operated farms, since mortgages did not concern the operators of rented farms. In discussing other credit the 15 rented farms will be included, making a total of 272 farms.

The primary interest in short-term credit on the part of those who are extending this credit is the number of farms using it and the amount used per farm. Surveys such as this one have been made for this purpose, the results published, and many of the studies declared good.

However, there are a few difficulties encountered in discussing short-term credit which have not been cleared up: (1) What is short-term credit? (2) To what crop year does short-term credit apply? The crop year in which the loan is made, or the crop years during which it is outstanding if it runs for more than 12 months? (3) Another difficulty arises from those studies which ask "How were expenses paid? — Cash, Open Account, or Note?"; namely, What constitutes cash, open account, or note in meeting an expense?

In the discussion of short-term credit the impression has often been given that the credit was used for one crop season. If that is the case, then practically no one has discussed "intermediate" credit, which is often used for purchase of machinery, tractors, trucks, autos, dairy cows, etc. Unpublished data from a study of credit use by G. W. Hedlund at Cornell shows $105,815 credit on notes during the crop year 1930-31. However, he reports $241,329 outstanding on notes payable at the end of the year.

Furthermore, credit obtained by open-book accounts or merchant credit is not very well defined. Some have said that accounts which run for more than 30 days constitute merchant credit. However, it is the common practice of one of the large grain distributors in this State to make an extra charge if grain is not paid for in 10 days after delivery.

In applying short-term credit to one particular year, the definition used makes a great deal of difference. If short-term credit is only that which is borrowed and paid off in the same year, the problem is simplified; but what, then, is to become of that credit which is carried along for more than one year, even though it was intended to be repaid in one year?

In trying to determine the amount of credit used in one year on the basis of how payment was made to meet expenses, the problems are many. In a study made in Massachusetts by Miss J. E. Donley in 1934, it was reported that 0.8 percent of the expenses was paid by notes which totaled $9,890. However, of notes outstanding at the end of the year, $48,135 had been made in the year covered by the report on how expenses were paid. In other words, cash had been obtained from notes and paid to meet expenses. Adding up the amount of open-book credit used in a year presents a further problem. If a farmer is always a month behind in meeting his feed bill, does that constitute one month's feed bill of open-book credit, or was all his feed bought on open-book credit?

The problems do not cease with a definition of terms, application of credit to one year, or determining the amount of credit used. The problem of the survey method and the idiosyncracies of the farmer remain. In a survey, the whole year's business is reviewed in one or two hours' visit. Bills and debts are things which farmers, along with others, wish to forget and when they are paid there is ample justification for putting them out of mind. Great faith is put in surveys; but to believe that a reliable figure on all the credit transactions of a farmer's business for a year can be obtained in this way, strains faith in the survey's results to the breaking point.

Since this study is based on a personal interview survey, an inventory of credit outstanding as of March 1, 1941, is depended upon to determine credit use. Instead of trying to determine what constitutes short-term credit, this classification was used: notes, open-accounts, unpaid taxes, past-due interest and/or principal payments on mortgages, and loans from life insurance companies secured by life insurance policies. The total amount of these types of credit outstanding is shown in Table 26.

The average amount of outstanding debt other than mortgages was $715. However, at least 70 percent of the farms did not owe this amount. About a third of the farms had none of this debt; and 71 percent was owed by 18 percent of the farmers, who owed more than $1,000 per farm and owned only 30 percent of the assets other than land and buildings. The ratio between their debts and assets was 1:2.1.

Table 26.—Frequency Distribution of Farms on Basis of Amount of Debt Outstanding Other Than Mortgages, March 1, 1941, 272 *Massachusetts Farms.*

Amount of Current Debt Outstanding (Dollars)	Farms		Current Debt		Average Current Ratio*
	Number	Percent of Total	Total Amount	Percent of Total	
0	88	32	0		
1 – 200	40	15	$4,856	3	1:16
201 – 400	37	14	11,107	6	1:9
401 – 600	21	8	10,326	5	1:6
601 – 800	22	8	15,403	8	1:6
801 – 1,000	15	5	13,770	7	1:3
1,001 – 2,000	31	11	42,593	22	1:3
2,001 – 3,000	11	4	27,920	14	1:3
3,001 – 20,000	7	3	68,503	35	1:1
Total	272	100	$194,478	100	1:5

*Current ratio is the ratio of current debt (all debt other than mortgages) to current assets (all assets other than land and buildings). The debt equals "1"; assets are shown as the number of times they were larger than the debt.

It is difficult to generalize on why the debts were so high on a small group of farms. However, most of the debt on farms owing over $1,000 represented an accumulation of losses in the farming operations; in a few instances notes had been used instead of mortgages to finance long-time obligations like buying the farm or putting up buildings; and in a few other cases this large debt was owed by those who were just getting started in farming or had very large operations.

The amount of debt was not the only criterion for judging the current ratio, Some types of farming, namely tobacco and onions, require only a small investment in current assets and a number of these had a low current ratio with a small debt.

As has been pointed out, it is difficult to separate strictly short-term or operating credit for one season from intermediate credit. From statistics contained in the "Agricultural Finance Review,"[5] it appears that seasonality of short-term credit is relatively unimportant in Massachusetts, since notes to individuals do not vary appreciably from January 1 to July 1 in the amount outstanding (Table 27).

---

[5] Agricultural Finance Review, U. S. Dept. Agr., Bur. Agr. Econ., 4 (2): 91-92. 1941.

Table 27.—Agricultural Loans Other Than Real Estate Outstanding by Selected Agencies, January 1, *and July* 1, 1941, *Massachusetts.*

Loaning Agency	Amount Outstanding		July as Percent of January
	January 1 1941	July 1 1941	
Insured Commercial Bank..........	$1,943,000	$1,858,000	96
Production Credit Association.......	626,000	768,000	123
Emergency Crop and Feed (F. C. A.)	48,000	67,000	140
Rural Rehabilitation (F. S. A.)......	508,000	536,000	106
Total.........................	$3,125,000	$3,229,000	103

The agency which showed the greatest seasonal variation in loans outstanding was the Farm Credit Administration's Emergency Crop and Feed loans. Even their loans were more than two-thirds as large in January as in July. Of course there are trends in the amount being loaned by these different agencies from year to year, but the trend is not sufficient to account for the small spread between January 1 loans and July 1 loans. The fact is that the amount of loans other than real estate mortgages continues at a high level throughout the year. The seasonality on individual farms will be greater than for farming as a whole; but by necessity, since the amount loaned by agencies does not vary considerably by seasons, the amount outstanding on individual farms must in a large part be fairly constant.

In reality it appears that "short-term" and "intermediate-term" credit have become a source for long-time credit, the difference being that the security is different and the refinancing is much more frequent. As has already been pointed out, most of the current debt owed by those with debts over $1,000 for other than mortgages was for the purpose of financing losses in their farming operations. Many of the other smaller borrowers use this credit to buy machinery, to meet feed bills, etc. They never get caught up — when they pay one debt they incur another, or they use an open-book account on feed and are always behind.

Notes

The total amount of notes outstanding amounted to 57 percent of the credit other than mortgages. The number of farms using notes and the number of notes per farm is shown in Table 28. Nine percent of the farms, with notes totaling over $1,000, owed 75 percent of the amount outstanding on notes. Sixty-one percent of the farms had no notes outstanding. Of the 106 which owed on notes, 58 percent were in debt on only one note, and 13 percent had more than two notes.

Table 28.—Frequency Distribution of Farms by Amount Outstanding on Notes March 1, 1941, 272 *Massachusetts Farms.*

Amount Outstanding on Notes (Dollars)	Number of Farms	Notes per Farm				Amount Owed	Percent	
		1	2	3	Over 3		Farms	Debt
		Number of Farms						
0	166						61	
1 – 200	34	30	4			$3,787	12	3
201 – 400	20	13	5	1	1	6,045	7	6
401 – 600	14	6	6	2		7,163	5	6
601 – 800	11	5	4	2		7,818	4	7
801 – 1,000	4	2	1	1		3,705	2	3
1,001 – 3,000	18	3	8	4	3	30,434	7	28
3,001 – 20,000	5	2	3			51,531	2	47
Total.........	272	61	31	10	4	$110,483	100	100

A discussion of notes is made difficult by the fact that a small proportion of the borrowers owed such a large proportion of the amount outstanding. If emphasis is placed on the bulk of the borrowers, insufficient attention would be paid to the large proportion of the debt represented. To get around this difficulty, frequency distribution of notes by amount outstanding is used.

Another difficulty results from the fact that a farmer may borrow from more than one source (22 percent of the borrowers had notes from two sources and 8 percent from three or more). This is further complicated by the fact that individual farmers may borrow more than once from the same source at different times (19 percent of the borrowers had done this). To overcome this difficulty, individual notes rather than individual farms are used in sorting. However, this inflates the number of borrowers under each sort to the extent that borrowing more than once from the same source had been carried on.

The sources which had loaned the money on the notes outstanding are shown in Table 29. As has already been pointed out, most of the borrowers had less than the average amount of credit on notes, but the largest amount of credit was represented by notes of over $1,000. The average size of note for each source (Table 29) indicates where the bulk of the notes fell for each source. Banks, which held 48 percent of the notes and 47 percent of the amount outstanding, were the only ones which covered the entire range of sizes of notes in the same proportion as all sources. The notes by others (especially individuals) were large. Company

Table 29.—Sources of Notes Outstanding on 106 *Massachusetts Farms, March* 1, 1941.

Source of Note	Number of Notes	Amount Outstanding	Average Size of Note	Percent Notes	Percent Amount Outstanding
Banks	82	$51,797	$632	48	47
Company Finance	27	8,212	304	16	7
Dealers	21	6,640	316	12	6
Production Credit Association	11	4,803	437	6	4
Farm Security Administration	7	5,898	842	4	5
Personal Finance	6	592	99	4	1
Morris Plan	3	775	258	2	1
Other	13	31,766	2,444	8	29
Total	170	$110,483	$650	100	100

Table 30.—Purpose of Notes Outstanding on 106 *Massachusetts Farms, March* 1, 1941.

Amount Outstanding per Note (Dollars)	Number of Notes by Purposes							Total
	General Expense	Tractor Truck and Car	Other Machinery	Livestock	Building	Hurricane	Other*	
1 – 200	20	12	18	13	3		8	74
201 – 400	10	14	7	9	1			41
401 – 600	10	6	3	4	2			25
601 – 800	4		4					8
801 – 1,000	2		1	5				8
1,001 – 3,000	3			2	1		3	9
3,001 and over	1		1		1	2		5
Total								
Notes	50	32	34	33	8	2	11	170
Amount	$29,868	$8,587	$14,048	$14,374	$10,400	$26,000	$7,206	$110,483
Percent								
Notes	30	19	20	19	5	1	6	100
Amount	27	8	13	13	9	24	6	100

*Taxes and licenses.......4 notes, $226
Sickness...............2 notes, 2,146
Land..................2 notes, 2,700
Unknown..............3 notes, 2,134

finance and dealers represent largely installment credit. The personal finance credit was the most expensive type, but the amount borrowed from this source was small.

The purpose of any note is to supply funds which the borrower does not have at the time they are needed. Thus most borrowing takes place when some large expenditure such as the purchase of fertilizer, a tractor, or several cows takes place. The purpose of borrowing for notes outstanding is shown in Table 30.

General expense, including fertilizer and feed, was the principal purpose for which notes were outstanding — 30 percent of the notes and 27 percent of the amount. Purchase of automotive equipment, other machinery, and livestock each accounted for about 20 percent of the notes, but the amount of the loans was 9, 13, and 13 percent respectively. Among the remaining notes were some of the largest and the smallest. These also included some for building and purchase of land, which might better have been secured by mortgages. Some of the smallest notes in this group were made for paying taxes. The two largest had been made by fruit farmers to meet expenses which resulted from the hurricane and accounted for 24 percent of the amount outstanding.

The proportion of the notes from each source used for different purposes is shown in Table 31. Banks were the only agencies which held notes for all the purposes listed. The purposes of notes from banks were in somewhat the same proportion as the purposes of all notes, although the banks were low in automotive and other machinery financing. Automotive and machinery financing were uppermost for company finance and dealers. The number of cases is so small that the proportion in different purposes shown for other sources is questionable.

Table 31.—*Frequency Distribution of Notes Outstanding by Source and Purpose on* 106 *Massachusetts Farms, March* 1, 1941.

Source of Note	Number of Notes by Purposes							Total
	General Expense	Tractor Truck and Car	Other Machinery	Livestock	Building	Hurricane	Other	
Bank	32	13	9	21	4	1	2	82
Company Finance		15	9	2	1			27
Dealers	1	3	11	5			1	21
Production Credit Association	7	1	1	2				11
Farm Security Administration	4			2	1			7
Personal Finance	2		1				3	6
Morris Plan			1				2	3
Other	4		2	1	2	1	3	13
Total	50	32	34	33	8	2	11	170
	Percent of Notes by Purposes							
Bank	39	16	11	26	5	1	2	100
Company Finance		56	33	7	4			100
Dealers	5	14	52	24			5	100
Production Credit Association	64	9	9	18				100
Farm Security Administration	57			29	14			100
Personal Finance	33		17				50	100
Morris Plan			33				67	100
Other	31		15	8	15	8	23	100
Total	30	19	20	19	5	1	6	100

It is difficult to determine how long notes have been outstanding. If the note has simply been renewed as it came due, the task becomes easier. However, refinancing through different sources or some other refinancing would show a younger note than the original borrowing. Neverthless, the best approximation which can be obtained by questioning farmers gives an idea of the long time which some notes run, and is shown in Table 32. Instead of sorting the notes for size on the basis of the amount due, the original amount of the note was used.

Table 32.—Age of Notes Outstanding on 106 *Massachusetts Farms, March* 1, 1941 — *Showing Original Amount of Note.*

Original Amt. per Note (Dollars)	Number of Notes by Months Outstanding							Total	Percent
	1-4	5-8	9-12	13-24	25-36	37-204	Unknown		
2– 200	9	6	11	7	2		1	36	21
201– 400	9	8	11	9	4	2		43	25
401– 600	7	7	13	5	2	1		35	21
601– 800	2	4	2	4				12	7
801– 1.000	2	2	5		3	1		13	8
1,001– 3,000	1	2	6	5	1	4		19	11
3,001–16,000					2	2		4	2
Unknown		1		2	2		3	8	5
Total									
Notes	30	30	48	32	16	10	4	170	
Amount	$10,717	$11.773	$15,023	$19,571	$34,815	$16,385	$2,199	$110,483	
Percent									
Notes	18	18	28	19	9	6	2		100
Amount	10	11	13	18	31	15	2	100	

Of the notes outstanding, 64 percent had been made within a year of the inventory date, 19 percent within two years, 9 percent within three years, and 6 percent were over three years old. One note had run for 17 years. The amount of credit that had been outstanding over a year was 64 percent. However, some of the notes which had run for longer periods were not for large amounts. Half of those which had run over two years and 30 percent of those which had run over three years were originally written for $600 or less.

Of the notes made during all periods, 67 percent were originally for $600 or less. This checks closely with the amount of notes outstanding per farm, which shows 64 percent of farms with notes owing $600 or less on them.

Summary of Notes

In comparison with mortgages, notes were distinctly of secondary importance in amount outstanding. On the 257 owner-operated farms, notes were 13 percent and mortgages 78 percent of the total debt. However, of the debt other than mortgages, notes were of primary importance, comprising 57 percent of this debt. With respect to the number of borrowers, open accounts were slightly more important; only 39 percent of the farmers had notes outstanding, while 48 percent were in debt on open accounts.

The amount outstanding on notes averaged $406 for all farms and $1042 for those with notes; and ranged from $21 to $20,000. Of the notes outstanding, 64 percent were for no more than $600, but these accounted for only 15 percent of the total amount due on notes. On 67 percent of the notes the original amount was no more than $600.

Banks, the principal source of note credit, held 48 percent of the notes and 47 percent of the amount due. Finance companies, which were primarily subsidiaries of manufacturers, were next in importance with 28 percent of the notes and 13 percent of the amount due. However, the Bureau of Agricultural Economics reports for Massachusetts that Production Credit Association, Farm Credit Administration through Emergency Crop and Feed loans, and Farm Security Administration through Rural Rehabilitation loans had 61 percent as much credit as insured commercial banks in agricultural loans other than real estate on January 1, 1941. This was slightly more than twice the proportion indicated by this study.

General farm expense and purchase of automotive equipment, other machinery, and livestock were the purposes given for 88 percent of the notes and accounted for 61 percent of the amount outstanding. Two notes by fruit growers for the repair of hurricane damage accounted for 24 percent of the amount outstanding on notes.

Banks held notes for all purposes. Many of the notes for automotive equipment and other machinery were held by dealers and manufacturers' subsidiary finance companies.

Notes ranged in age from less than a month to 17 years. Sixty-four percent had been made within a year of the inventory date, but the amount outstanding on these notes was only 34 percent of the amount due. However, there were small notes as well as large ones that had been outstanding for more than two years.

Open Accounts

Open accounts in this study mean unpaid bills that were still due March 1, 1941, when all that could be paid on bills had been paid. If it was the farmer's practice to get grain during the month and pay for it when he got his milk check, this was not considered an open account. However, if the grain dealer required payment within ten days and this had run over and was due at the beginning of the month, this was considered an open account. So far as possible all of these open accounts refer to March 1, 1941. The number of farms with open accounts, the amount owed per farm, and the number of accounts per farm are shown in Table 33.

Table 33.—Frequency Distribution of Farms Showing Amount Owed and Number of Open Accounts per Farm on 272 Massachusetts Farms, March 1, 1941.

Amount Outstanding on Open Accounts (Dollars)	Number of Farms	Open Accounts per Farm					Amount Owed	Percent	
		1	2	3	Over 3	Unknown		Farms	Debts
		Number of Farms							
0	143							52	
1 – 200	56	41	11	2	2		$6,585	21	12
201 – 400	32	19	11			2	9,434	12	16
401 – 600	13	8	5				6,070	5	11
601 – 800	11	6	3	1	1		7,663	4	13
801 – 1,000	5	3				2	4,850	2	8
1,001 – 5,300	12	7	3		1	1	23,257	4	40
Total	272	84	33	3	4	5	$57,859	100	100

Of the 272 farmers, 52 percent had no open accounts; 48 percent were borrowing on open accounts; and 15 percent were borrowing over $400 per farm and owed 72 percent of this type of credit. The average debt on open accounts for those who used this type of credit was $449. Of those who had open accounts, 65 percent indicated only one account and 26 percent two accounts. Very few farmers had more than two accounts, although one or two farmers had seven or eight.

Although a few farmers owed a friend or relative small amounts for fertilizer or other supplies, the source of open-account credit in practically all cases was a seller. No buyers of agricultural products were indicated by the farmers as advancing credit, although this probably does occur to a limited extent.

Table 34.—*Purposes of Open Accounts on* 129 *Massachusetts Farms, March* 1, 1941.

Amount Outstanding on Open Accounts (Dollars)	Number of Accounts by Purpose				Total
	Grain	Supplies	Cows	Other	
1 – 200	54	35	4	16	109
201 – 400	22	7	2	2	33
401 – 600	6	3	1	1	11
601 – 800	5	4			9
801 – 1,000		4	2		6
1,001 – 5,300	6	5			11
Total					
Accounts	93	58	9	19	179
Amount	$28,183	$23,565	$3,670	$2,441	$57,859
Percent					
Accounts	52	32	5	11	100
Amount	49	41	6	4	100

The purposes for open accounts are shown in Table 34. About half of all the accounts and the credit was used for purchase of grain. Supplies, which includes fertilizer, seed, spray, hardware, etc., accounted for about a third of the accounts and 41 percent of the credit. Open accounts were not used to any great extent for the purchase of cows. Other open accounts such as garage, water, insurance, etc., were also of minor importance.

Poultrymen had most of the large open-book accounts for feed; but this did not necessarily mean that they weren't doing well.

Many of the open-book accounts were a continuing source of credit. This amount would vary from time to time. Some of the accounts had remained at a high level while current bills had been paid. In some cases farmers continued to patronize dealers whose prices were higher because they had built up an account with them. These accounts were largely a result of difficulties in maintaining an income.

Unpaid Taxes

Unpaid taxes are not usually thought of as credit. However, it is difficult to differentiate between an unpaid bill for grain or a machine and unpaid taxes. Furthermore, if a loan is made to pay taxes, then that loan becomes credit. Most of this credit, though, is borrowed from the town simply by not paying the taxes and the town charges interest. Unpaid taxes are not a recommended source of credit, because of the great liability involved.

Table 35.—Frequency Distribution of Farms Showing Amount and Years of Unpaid Taxes Outstanding per Farm, 272 *Massachusetts Farms, March* 1, 1941.

Unpaid Taxes per Farm (Dollars)	Number of Farms by Years Unpaid		Total Farms	Amount Outstanding (Dollars)	Percent	
	1940	1939-& 40			Farms	Amount
0			213		78	
1 – 100	10	–	10	830	4	6
101 – 200	22	1	23	3,515	8	28
201 – 300	11	5	16	4,031	6	32
301 – 1,000	6	4	10	4,327	4	34
Total						
Farms	49	10	272		100	
Amount	$9,819	$2,884		$12,703		100
Percent						
Farms	18	4	100			
Amount	77	23		100		

Rented as well as owner-operated farms are considered in discussing unpaid taxes, since personal property taxes are levied on them. The number of farms with unpaid taxes and the amount and years unpaid are shown in Table 35. On March 1, 1941, 22 percent of the farms had unpaid taxes, 18 percent were delinquent for 1940 and 4 percent for 1939 and 1940. The average amount unpaid per delinquent farm was $215.

From a study made of tax delinquency in Massachusetts[6] for 1928–33, it was reported that 63 percent of the area in farms in 37 towns was delinquent in 1928. For 1932 this figure was 85 percent. Therefore, it appears that a farmer who pays his taxes on time is an exception to the rule. This report also states that in April 1934, 35 percent of the area in farms was delinquent on taxes levied from 1928 to 1932.

Since 1934 was one of the highest years in tax delinquency, it would not be reasonable to make any comparison with figures for that year. Furthermore, the delinquency figure on April 1934 does not include delinquencies for the year 1933 which would have made the figure much higher. However, the tax delinquency shown by the 1935 study does indicate that even in fairly normal years almost two-thirds of the farmers do not pay their taxes on time. This may indicate a poor farm financial condition. However, it probably indicates simply that unpaid taxes are a very convenient source of short-term credit used by a great many farmers.

The difference between approximately 65 percent and 22 percent of farms with unpaid taxes may be caused largely by the difference in inventory date. Possibly a large proportion of the farmers had not paid their 1940 taxes when they were due but had paid them by March 1, 1941.

Mortgage Interest and/or Principal Past Due

Mortgage interest and/or principal is a charge which a farmer must meet or else subject himself to the possibility of losing his farm through foreclosure. When this charge is past due, however, a credit has been set up; although it may be more an indication of financial weakness on the part of the borrower than it is a credit.

---

[6] U. S. Dept. Agr., Bur. Agr. Econ., Div. Agr. Finance, "Tax Delinquency of Rural Real Estate in 37 Massachusetts Towns, 1928-33," September 19, 1935.

There were 20 farmers who had past-due mortgage interest and/or principal payments. They represented 8 percent of owner-operated farms and 11 percent of the 177 mortgaged farms. The amount owed ranged from $6 to $700 and averaged $214 per indebted farm. Nine of the farms were behind from 3 to 9 months, eight were 12 months behind, two were 18 months behind, and one was 24 months behind.

Of these 20 farms, 13 had only a first mortgage, 5 had second mortgages, and 2 had third mortgages. The total was 29 mortgages, of which 9 were with the Federal Land Bank, 7 were with individuals, 6 were with banks, 3 were with Land Bank Commissioner, and 4 were with other creditors. Of the 8 Farm Security Administration clients found in this study, 5 were in this group with past-due mortgage payments.

An inherent lack of capacity on the part of the farmer or his farm, either past or present, was a characteristic of 17 of these 20 farms. The other 3 were victims of expansion and going into debt at high prices. Probably about half of the 20 farmers, either through their own efforts or with the help of an agency like Farm Security Administration, will succeed in keeping their present farm. The other half will probably go out of farming or should be shifted to another farm. All of those who suffered from price changes will probably succeed. Those who will probably succeed were either pulling out of debt or would start as soon as a little help and guidance arrived. These things are pointed out simply to show that even though the debt which these farmers had was serious, still, it was a line of credit. If treated as credit, it might help in pulling at least half of them through a difficult situation.

Loans on Life Insurance Policy

Loans on a life insurance policy are in some ways costly when it is realized that the interest paid on the loan is 6 percent whereas the interest received on the money invested in them is much less. However, it is a comparatively simple loan to get. The only security required is the cash value of the policy.

In this study 171 or 63 percent of the farmers had life insurance policies, and 16 of them or 9 percent had borrowed on their life insurance. The amount borrowed ranged from $100 to $2,000 and averaged $572. Twelve of these borrowers also had mortgages, but two had loans only on their life insurance. The type of policy carried by the 171 farmers and by the 16 who had loans is shown in Table 36.

Table 36.—*Types of Life Insurance Policies held by Farmers and Types upon Which Loans were Made,* 272 *Massachusetts Farms,* 1941.

Type of Policy	Farmers with Life Insurance		Farmers with Loans on Life Insurance	
	Number	Percent	Number	Percent
Straight life	73	43	8	50
Limited payment life	32*	19	2	13
Endowment	33**	19	5	31
Several	7	4	1	6
Unknown	26	15	–	–
Total	171	100	16	100

*One of these also had a straight life policy.

**12 of these had other policies which were either straight life or limited payment.

The type of policy on which loans were made is not particularly important. However, it does show that a slightly higher proportion of those with endowment policies had borrowed on their life insurance. Furthermore, the fact that 19 percent of the farmers with life insurance had endowment policies is also of note. A little more than half of these also had mortgages. For those with endowment policies and mortgages, the best plan would have been to pay off the mortgage before investing in endowment insurance.[7]

Summary of Credit Use

Only 16 percent of the farmers interviewed were not using some credit. Mortgages were by far the most important type of credit both from the point of view of the proportion of farmers using them and the proportion of the total debt on farms. The largest number of mortgages was for no more than $3,000, but most of the total mortgage debt was represented by mortgages over $3,000 in size.

The four most important sources of present mortgages were banks, Federal Land Bank, individuals, and Land Bank Commissioner. Banks and individuals were the most important sources of mortgage credit when these farms were originally acquired; but, by refinancing, the Federal Land Bank and Land Bank Commissioner had reached a comparatively high level of importance.

Less than half the farms which started with a mortgage were mortgage-free after 30 years. However, most mortgage contracts, even on these farms which had been mortgaged for 30 years, had been outstanding a shorter time than this because the original contract had been refinanced. Mortgage refinancing appeared to be rather widespread.[8]

"Short-term" credit is not discussed as a separate item. Credit other than mortgages is discussed as notes, open accounts, etc. Nearly two-thirds of the farms had some credit other than mortgages.

Notes were outstanding on about two-fifths of the farms March 1, 1941. Both the amount outstanding per farm and the original amount per note were in most cases no more than $600. However, as with mortgages, the largest total dollar volume of notes was represented by the larger notes.

Almost half of all the business in notes was done with banks. Dealers or the companies they represented held about a fourth of the notes. Although individuals were a relatively unimportant source of credit on notes in numbers, they held several large notes which were about a fourth of the amount of all notes outstanding.

Most of the notes had been made for general farm expenses, equipment, and livestock. However, notes for building and the repair of hurricane damage accounted for a third of the dollar volume. The notes with banks covered the widest range of purposes.

Nearly two-thirds of the notes had been outstanding less than a year, but two-thirds of the amount due on notes had been outstanding more than a year. Credit by notes does not seem to have a very high degree of seasonality, and, especially from the point of view of loaning agencies, has a fairly constant year-round volume.[9]

About half of the farms were using open accounts as a source of credit. Most of the accounts were for no more than $400. Grain and supplies such as fertilizer, hardware, and seed were the main items purchased on open accounts. Many of the large accounts were owed by poultrymen and represented bills which accumulated during a low-income period.

---

[7] An endowment policy combines both insurance and investment. The farmer with a mortgage who invests in an endowment policy uses funds in meeting policy payments which would yield a higher return if used to pay off the mortgage.

[8] For more detailed summary of mortgages, see summary for that section, p. 20.

[9] For more detailed summary of notes, see the summary for that section, p. 26.

About a fifth of the farms had unpaid taxes on March 1, 1941. From other studies of taxes it appeared that most farmers use unpaid taxes as a source of credit for a short time.

Mortgage interest and/or principal payments were past due on about a tenth of the mortgaged farms. On about half of these farms the past-due amounts could be considered a source of credit which might help in enabling them to get through a poor financial period.

About a tenth of those who had life insurance had borrowed on their policy. These loans as well as unpaid taxes and mortgage payments were minor as far as total credit used on all farms was concerned.

ADEQUACY OF PRESENT CREDIT FACILITIES

With few exceptions, the consensus of opinion is that there is an adequate supply of credit available to farmers. Both private and government-sponsored agencies are anxious to do business with farmers. Even the less desirable risks can obtain necessary loans through the Farm Security Administration. Not only is the volume of credit sufficient, but the rates of payment need be no more than 6 percent.

When farmers were asked, "Do you need more capital than you have or have been able to get?" a common answer was, "I could use more and get it, but I don't know how it could be paid back." In 82 percent of the cases the farmers said that they borrowed all the money that they wanted. The remaining 18 percent have been studied in an attempt to see whether or not there was any deficiency in the credit institutions. As might be expected, all of the farmers who expressed a need for more credit were already borrowing (Tables 37 and 38).

Table 37.—Frequency Distribution of Total Debt on Farms Needing More Credit, 272 Massachusetts Farms, 1941.

Total Debt per Farm (Dollars)	All Farms	Farms Needing More Credit	
		Number	Percent
0	43	–	0
1 – 1,500	70	12	17
1,501 – 3,000	60	11	18
3,001 – 4,500	39	13	33
4,501 – 6,000	34	4	14
6,001 – 62,000	26	9	35
Total	272	49	18

Table 38.—Frequency Distribution of Net Worth in Total Assets on Farms Needing More Credit, 272 *Massachusetts Farms,* 1941.

Percent Total Net Worth per Farm	All Farms	Farms Needing More Credit	
		Number	Percent
100	43	–	0
75 – 99	91	11	12
50 – 74	97	24	25
25 – 49	32	12	38
1 – 24	7	2	28
0 or less	2	–	0
Total	272	49	18

There was a tendency for the proportion expressing need for more credit to be higher among those who had a large debt or a low percentage of net worth. This was natural if the credit institutions were supplying funds adequately, for if a farmer has no debt or only a small proportional debt he would be a good financial risk. Therefore, he would not experience any restraint if he wanted new credit.

Since the farmers who expressed a need for more credit all had debt, the next question is how many were good risks. On the basis of all the knowledge about the farm and the farmer, 30 of the 49 appeared to be satisfactory risks. Of the remainder, 5 had personalities or connections other than farming which made it impossible to classify them, and the other 14 were undesirable risks.

On further classifying those with a satisfactory credit rating, 5 appeared to be seeking either a too rapid or an unjustified expansion; 8 were just getting started or had started an expansion which they needed to consolidate before going further; 14 could get credit and either were arranging for it or were reluctant to borrow; and 3 needed some education on how to get good credit.

Those who were undesirable credit risks included 3 Farm Security Administration borrowers; one who was applying for a F. S. A. loan; 3 Personal Finance Company borrowers. The rest were poor managers or had low grade farms.

In no case was it felt that after approaching the proper agency would any of these farmers have been refused credit for a reasonable farm loan. Some felt that they could expand more or faster than a loaning agency would advance funds, but an examination of the businesses would seem to warrant refusal of a loan. Some of those who could borrow only from the Farm Security Administration at a reasonable rate of interest might have rebelled at supervision. However, it is a credit principle that the greater the risk the greater must be the supervision of the loan. Those who warranted F. S. A. loans needed supervision.

Another aspect of the adequacy of credit is the actual cost to the borrower. This calls for interpretation, since no reliable figures on actual cost[10] were obtained. It is estimated that about half of those who borrowed money were paying more than was necessary. High cost of credit was least widespread in the field of real estate mortgages. The main reason for much of this high cost credit was an inherent willingness to pay for convenience. Installment buying, with purchasing and financing residing in one person, along with open-book credit accounted for most of the high cost loans. However, opportunity exists to all to obtain all the necessary credit at reasonable rates. On the other hand, unless a much more stringent Government program of regulation and examination of all credit extended is instituted, high cost credit will continue to exist.

One aspect of the adequacy of credit which also needs attention is the ultimate goal of that credit. Thus far sufficient volume and low cost have received all the attention. If this becomes the only goal the result may be too much credit, which jeopardizes all borrowers. In Quershi's book, "Agricultural Credit," Joseph Johnston makes the following comment in the introduction:

> The fundamental defect of American agricultural credit policy in the post-War years was that it was an effort to finance the continued production of a volume of agricultural goods which, owing to various causes, could not possibly achieve complete consumption in markets at home or abroad. If America had pursued a commercial policy less exclusive of European industrial products in the years following 1928, it is possible that we should have heard less of the "uneconomic surpluses" of American wheat and cotton in the years following 1930.

A similar principle might be applied to Massachusetts agriculture. In times when there is an abnormal surplus of milk in some markets, it might be well to consider curtailment of production through curtailing credit. In periods of war or of food scarcity, the continuation of many people in agriculture through ample credit looks like a desirable policy. Nevertheless, it might be well to consider the need for ample agricultural credit in the light of volume of production and also to test more fully the capabilities of the borrower as a farmer.

---

[10] The reasons for not obtaining cost figures were: (1) Credit cost is not just a matter of interest rates on money. The total cost of credit may include incidental expenses, such as inspection fees, insurance policies, registration fees, search fees, and higher prices because of a credit sale. Other things which increase credit costs above stated interest rates are loan discounting, installment repayment where interest is charged on the full amount for the entire period. penalty charges for late payments, loan renewal charges, etc. (2) Closely connected with the fact that incidentals increase credit cost is the farmer's inability to remember and in some cases his complete unawareness of credit costs which he is bearing.

FACTORS AFFECTING A FARMER'S ABILITY TO REPAY LOANS

Much careful work has been done and many fine studies made on the relationship between certain objective factors and the success of loan repayment. Investigation along the same lines was started with the material in this study, but it soon became apparent that in reality a farm management study was being made. Thus it appears that, as far as ability to repay a loan is considered, the most important factors are farm management factors of success: adaptation of type of farming to the area; quality of the natural characteristics of the farm (soil, topography, etc.); quality and variety of the physical additions to the farm (building, machinery, livestock, water, electricity, etc.); operation of social institutions (taxes, prices, markets, roads); and immediate manifestations of the management ability of the operator on the farm (size of business, rates of production, labor efficiency, capital efficiency, diversification, etc.).

However, it was also recognized, more from stories by neighbor farmers than from the records themselves, that there are other factors which also affect repayment ability. Among these are: the rate of spending or level of living aspired to by the operator and his family; gifts and inheritances; and luck or so-called "acts of God" such as fire, hurricane, flood, or conversely a good gravel pit, good payment for roads put through the farm, etc.

Then there are some factors which concern the loans themselves and might have been discussed under the adequacy of credit facilities. These are pressure and method of repayment asked of the borrower to repay his loan; adaptation of the length of time a loan is to run to the repaying ability of the asset purchased; the relation of the size of loan to the value of the asset; and costs of the loan.

Some of these factors are outside the strict realm of ability to repay. Still further out there is another factor which is of importance, the attitude of the borrower toward paying loans.

The task of a scientific economist should be to measure the effect of each of these factors. This has not been done, for three reasons: first, to do this would require a record of the entire financial and social history of each farm; second, the separation of the effect of each factor appears an impossibility; and third, the measured average effect determined from any group of cases has little if any relationship to the effect in individual cases.

As far as repayment of loans is concerned, there are two main approaches used by the creditor. The first and probably the most common is, "Can the collateral be sold for as much as the amount of the loan or more?" In this case it is entirely up to the borrower to determine his ability to repay the loan. The second approach is, "Will this loan increase the borrower's earning capacity enough to enable him to pay back interest and the principal?" In this case the creditor tries to analyze the borrower and his business on the basis of the factors mentioned above. It is a more humane and social approach than the first, but it is more costly and takes more time. This approach is used primarily in granting short-time loans.

In general there is one reason if not more why every loan is or is not repaid. However, it is impossible to predict that any one reason or factor would assure success or failure in every case. Dr. D. O. Hammerberg at the University of Connecticut made an elaborate farm management study to determine factors or combinations of factors that would assure increased farm returns. After long and careful investigation he concluded that there were none that were dependable in all cases. The same is felt to be true of loan repayment, especially since it rests in large measure on farm management operation.

Loans are necessary and it is necessary that most of them be repaid. If a creditor prefers repayment in cash and not by the value of the collateral, he should then try to measure the chances for sufficient income and to judge the integrity of the borrower. Farm management factors of success will help to measure chances for income. The sociologist and the psychologist need to be called on to determine the integrity of a farmer.

SUMMARY, CONCLUSIONS, AND SUGGESTIONS

It is difficult to judge the financial condition of farmers in Massachusetts on the basis of a one-year survey. The income on each farm can vary considerably from year to year. The amount of income, with such things as gifts and the spending habits of the farm family ruled out, determines the direction which the farm financial position will take. One year's figures for this factor are inadequate. However, judging from the amount of debt, of assets, and of the relationship of the two, it appeared from this survey that roughly 50 percent of the farmers were doing well, 30 percent were getting along, and 20 percent were in poor financial condition.

Poor credit practices were being used, but not by a large percentage of the farmers. The worst practice was borrowing from so-called "personal or household finance companies" whose interest rates are 30–35 percent per year. About 2 or 3 percent of the farmers were doing this. Installment buying with interest rates ranging around 12 percent was another less desirable practice used by about 15 to 20 percent of the farmers. The use of open-book accounts with higher prices for purchases was another undesirable practice. It was not known how many were paying higher prices because they used open-book accounts.

The financing of operating losses presented one of the more difficult problems in farm financing. Crop failure, livestock disease, family sickness, price disparities, etc., may cause dollar losses which are hard to repay. Although such a loss can occur in one year, it usually takes several years to repay. If credit is used in financing current operations and this credit is written for payment in one year, the farmer may get a poor credit rating from such losses, through no fault of his own. The separation of this group, which suffers losses through no fault of their own, from the farmers who under no conditions can operate profitably needs more attention.

The farm credit policy appears to be that ample funds at low cost should be available to all who want to use the funds on a farm. Some effort is made to see whether the type of farming can be profitable. However, it does seem as though more attention should be paid to the entire economics of farming in the area around the farm. For instance, in an area which for profitable farming requires a Class I milk market, it seems undesirable to finance a dairy farmer if there is already a 50 percent surplus in that area.

Not only should the economics of the area be examined before making a loan, but also the qualifications of the farmer need attention, even though it is felt, particularly with mortgages, that the loan is based on the money value of the farm. Those who are making loans to farmers may say that farmers' qualifications are considered. The degree of success even in mortgage repayment may be high. However, loan repayment should be higher than it is at present. Industrial firms have been testing the qualifications of their employees for particular positions. The success attained over former subjective judgment has been great. It would seem reasonable that tests, psychological or otherwise, could be devised which would improve the success of loaning agencies in picking qualified farmers.

It has been found in this and other studies that farmers have difficulty in supplying an enumerator with the costs of credit. The stated contract interest rate is commonly known in case of mortgages and notes, but the net cost is usually unknown. Installment credit, short-term loans, and commodity loans are entirely without a concept of net cost. Education in the methods of figuring the true costs of these high-cost loans is needed. Further education would be helpful in informing borrowers of agencies which loan on short term at reasonable rates and how to secure loans from these insititutions.

Amortized farm mortgages are a common institution today. But amortization is not the complete answer to successful payment of mortgage loans. Recently, during periods of low farm prices, moratoriums on mortgage principal payments have been granted. Such policies, if sound, must also be accompanied by a provision for more rapid payment than the amortization plan calls for to operate when farm prices are higher. At least one large credit institution in this area has made provision for advanced future payments. The plan is working very satisfactorily. The gearing of payments to farm income levels appears to be logical.

One of the difficulties in the granting of credit to farmers has been the lack of adequate records and statements. This condition may be changing. The necessity for reporting income for income and victory tax purposes may force better bookkeeping upon farmers. One of the indirect results will be a better basis for credit extension.

Certain government agencies and a few private lenders have followed their loans with a considerable amount of farm management supervision. It should be a principle that the higher the loan risk, the greater the right of supervision. When effectively applied, it should be welcomed by the borrower as a means of increasing income out of which to pay his debts.

APPENDIX

(Questionnaire used in the Study)

RURAL CREDIT

Prepared by Department of Agricultural Economics and Farm Management
Massachusetts Experiment Station, Amherst, Mass.

All information in this Survey is STRICTLY CONFIDENTIAL

Record No............. Enumerator.................... Date..........

Name of Operator.......................... Town ....

Address.................................... County ....

Kind of road........ Cond. of bldgs.: Paint.......Repair.......Clean.......Farmer's.......

Distance to hard road.......Mi. Market {Milk......................Distance .... Mi.
Poultry ....Distance .... Mi.
....Distance .... Mi.

Mkt. Retail.............. Wholesale..............

Age operator.... Yrs. Farming.... This farm........ Other skill......................

Others in family (No.).... Boys (Ages).... .... Girls (Ages).... ....

...... Other...... .... Time worked on farm............................

Farm acquired: Date.......... Price $........ Cash $.......... Mortgage $........

Relationship to previous owner................ Mortgage holder.......................

Improvements since acquiring farm..

.... Cost $............

Do you need more capital?.......... How much?.......... For how long?..............

For what purpose?...

Accounts Kept: Inventory.......... Cash Acct........... Savings.......... Checking....

Other ....

Past Credit Experience: Explain — Default, Bankruptcy, Foreclosures, Rejections, etc.

....

....

Condition of surrounding farms: Size........ Repair........ Type........ Farmer's ....

Productivity of soil............ Drainage............ Ease of operation...............

How does this farmer use credit (short-term credit for buildings, loans for needless equipment or unjustified living standards, etc.) Explain..

....

....

....

Remarks:

DEBTS

(Outstanding and those paid off during the year)

Real Estate Mortgages

Security	Amount Original	Present	Time Given	Due	Holder	Rate	Payments Amount	When	Purpose of Loan
1st......	......	......	......	......	......	......	......	......	....
2nd	......	......	......	......	......	......	......	......	....
....	......	......	......	......	......	......	......	......	....

Notes (Bank, Feed, Fertilizer, Cattle, Equip., Truck, Auto, Tractor, Refrig. etc.*)

Purpose and Holder	Amount Original	Present	Time Given	Due	Interest Rate	Amt.	Cash Price	Credit Price	Payments No.	Amt.
1	......	......	......	......	......	......	......	......	......	....
**..										
2	......	......	......	......	......	......	......	......	......	....
**..										
3	......	......	......	......	......	......	......	......	......	....
**..										
4	......	......	......	......	......	......	......	......	......	....
**..										
5	......	......	......	......	......	......	......	......	......	....
**..										
6	......	......	......	......	......	......	......	......	......	....
**..										
7	......	......	......	......	......	......	......	......	......	....
**..										

*Include all chattel mortgages, crop liens and installment purchases.

**Explain how interest is figured, plans for repayment, etc.

Accounts (Feed, Fertilizer, Cattle, Garage, Lumber, Groceries, Doctors, etc.)

Purpose and Holder	Amount Present	Cash Price	Credit Price	Time Started	Can Run	Highest Amount	Charges
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....

Unpaid taxes for the years 19.... 19.... 19.... ....

Mortgage interest and principal past due ....

Loans secured by life insurance from insurance company.................... ....

Notes indorsed for others.. ....

Total Liabilities........................ ....

ASSETS

Value Owned

Sale value of farm—...... (......a Own ......a Rent) ......a Crop ...... a Past ......a Other Houses...... Barns...... .... Silo...... ......

Assessed value of farm.................... Other real estate.................... ......

Horses: No....... Value......; Tractor: Size...... Value...... ....

Cattle: (No. & Value) Cows..... ..... Young Stock..... ..... Other..... ....

Poultry: (No. & Value) Laying hens..... ..... Pullets..... ..... Chicks..... ....

Other livestock (describe).. ......

Machinery & Equipment (list most important)................................ ......

....

Trucks and Automobiles: (No. and Value)..................................... ......

Feed and Supplies... ......

Farm Produce for Sale (describe).. ......

Notes and Accounts Receivable........... Cash on hand and in bank............ ......

Life Insurance (Amount........Kind........Age Policy........Premiums........) ......

Stocks, Bonds & Mortgage..............Other Assets............................ ......

Total ......

RECEIPTS

Crop or Product	Acres or No.	Production	Sales Amt.	Sales Value
....	......	......	......	......
....	......	......	......	......
....	......	......	......	......
....	......	......	......	......
....	......	......	......	......
....	......	......	......	......
....	......	......	......	......
....	......	......	......	......
Dy. Prod.	......	......	......	......
Cows....	......	......	......	......
Eggs.....	......	......	......	......
Hens....	......	......	......	......
A.C.P....	......	......	......	......
Other***	......	......	......	......
Outside Income	Source 1	.....	1	$.....
	2	.....	2	$.....

EXPENSES

	Amt.	Cash* Credit
Fertilizer..................	......	......
Seed......................	......	......
Spray.....................	......	......
Labor.....................	......	......
....	......	......
Feed and bedding........	......	......
Gas, oil, and coal.........	......	......
Supplies, containers, etc..	......	......
Equipment repairs.......	......	......
Building repairs..........	......	......
Other operating expense**.	......	......
Taxes.....................	......	......
Interest..................	......	......
Insurance................	......	......
Livestock purchased......	......	......
Equipment purchased.....	......	......
Permanent improvements.	......	......
Household & family exp...	......	......
Other....................	......	......
....	......	......

*Indicate cash (ca) or credit by note (crn) or credit by account (cra)

**Vet. testing, tel., elec., shoeing, rent, machinery hired, silo filling, dues, licenses, milk hauling.

***Include patronage dividends, prizes, maple syrup, wood, wool, etc.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

OCT 1 1943

Bulletin No. 406 July, 1943

Feeding Urea To Dairy Cows

By J. G. Archibald

The scarcity of protein concentrates has created an interest in the use of urea as a partial substitute in dairy rations. Tests of its desirability are reported here.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

FEEDING UREA TO DAIRY COWS[1]

By J. G. Archibald, Research Professor of Animal Husbandry

INTRODUCTION

The idea of using urea and other relatively simple nitrogenous compounds as substitutes for protein in the rations of farm animals is not a new one. Investigations bearing on the problem date back to the middle of the 19th century. In 1891 Zuntz (1) suggested that ruminants may obtain protein from nonprotein nitrogen through synthesis by the bacteria and other microorganisms normally found in the rumen or first stomach of this class of animals. The scarcity of nitrogenous concentrates in Germany during World War I and the development of processes for fixation of atmospheric nitrogen gave a great impetus to investigations suggested by the earlier work. Most of the work on the problem during and closely following the war was done in Germany. Numerous investigators there claimed to have shown that such compounds as urea, ammonium carbonate, and ammonium acetate could be utilized by the flora of the rumen for building up cellular proteins, which in turn could be digested in the abomasum or true stomach of the ruminant in the same manner as the preformed proteins of the ration.

More recent critical reviews have questioned the validity of these findings. Mitchell and Hamilton (2) in 1929 concluded "that the bacterial-protein theory of the utilization of non-protein substances by ruminants is still in the controversial stage." Krebs (3) in 1937 reviewed the whole subject and stated that the evidence was all based on feeding trials of insufficient length—that long-time trials are necessary in order to establish the theory on a sound basis. Marston (4) in 1939 wrote that "the hypothesis that protein in useful amounts is synthesized through the agency of the micro-flora of the rumen is, on the whole, far from convincing."

Along about 1930, manufacture of synthetic urea on a commercial basis became a reality in the United States. It was used at first largely for fertilizer, but as production expanded the manufacturers began to look for other outlets. The above-mentioned work suggested a possible market in the feed trade, but several investigators and E. I. DuPont de Nemours and Co., principal producers of urea in this country, felt that, in view of the unsettled status of the problem, further research should be conducted by American experiment stations. Urea feeding experiments, therefore, were initiated by several institutions including Hawaii, Illinois, Kansas, Massachusetts, New York (Cornell), and Wisconsin. The investigations have included experiments with beef cattle, dairy cattle, and sheep. At least four of these institutions are still investigating various phases of urea feeding; because of circumstances beyond its control, the Massachusetts station has been obliged to discontinue its urea feeding project for the duration of the war at least. This bulletin constitutes a report of the work done here from January, 1940, through December, 1942.

---

[1] Acknowledgement is made (1) of financial assistance from E. I. DuPont de Nemours and Company, Wilmington, Delaware, which made possible the conduct of this investigation; and (2) of the cooperation of the State Department of Mental Health, which made available facilities for the feeding trials at one of the State institutions under its control. Especial thanks are due to Mr. Rodman C. Nowers, Head Farmer at the Medfield State Hospital, who had immediate supervision of the feeding trials, and whose careful attention to the details of the work contributed in large measure to its success.

PLAN OF THE EXPERIMENT

When the project was organized in the autumn of 1939, because of priority of other investigations, there were no cattle available for the feeding trials in the herd at Massachusetts State College. An arrangement was made therefore with the State Department of Mental Health to utilize the milking herd at the Medfield State Hospital. This herd consists of approximately sixty Holstein cows, rather uniform in size, above average in production, and of the same general breeding.

Twenty-four cows were chosen for the work and were divided into two groups of eight and sixteen individuals respectively (see Table 1). The group of eight cows was designated as the "double reversal" group, and was further divided into two groups of four cows each, referred to in Table 1 as Groups A and B. These cows were alternated between the "urea" ration so-called, and the "regular" ration so-called at eight-week[2] intervals, with one week allowed in between for change-over. A period of thirty-two weeks (two eight-week periods for each group on each ration) in each of two successive lactation periods, was originally planned for, but this was shortened later to twenty-eight weeks because some individuals dried off sooner than anticipated.

The group of sixteen cows was designated as the "continuous" group, and was subdivided into two groups of eight cows each, referred to in Table 1 as Groups C and D. These sub-groups were kept continuously on the same ration for two complete, successive lactation periods, Group C on urea, Group D on the regular ration.

---

[2] Seven-week intervals in the second lactation.

TABLE 1. — COMPARATIVE DATA ON THE GROUPS OF COWS AT THE START OF THE FEEDING TRIALS IN JANUARY, 1940

	"Double Reversal" Groups			
	Group A		Group B	
	Range	Average	Range	Average
Age . . . . years and months . .	2-10 to 5-11	4-8	2-11 to 5-9	4-3
Stage in lactation . . . . day . .	5th to 21st	18th	2d to 21st	10th
Average daily milk yield in last lactation . . . . pounds . .	40 to 54	45	36 to 55	47
Average fat test of milk in last lactation . . . . percent . .	3.01 to 3.33	3.25	3.25 to 3.61	3.43
Live weight . . . . pounds* . .	1,070 to 1,355	1,238	1,090 to 1,340	1,178
General condition	. . . .	Good	. . . .	Good

	"Continuous" Groups			
	Group C		Group D	
Age . . . . years and months	2-4 to 6-4	4-4	2-7 to 7-5	4-7
Due date**	Jan. 13 to Mar. 22	Feb. 10	Feb. 2 to Apr. 32	Mar. 7
Average daily milk yield in last lactation . . . . pounds . .	35 to 45	40	37 to 44	40
Average fat test of milk in last lactation . . . . percent . .	3.13 to 3.62	3.36	3.04 to 3.60	3.38
Live weight . . . . pounds* . .	1,155 to 1,450	1,330	1,210 to 1,440	1,341
General condition	. . . .	Good	. . . .	Good

*Average of two weighings on consecutive days.

**At the start of the experiment in January, 1940, the cows in Group C and D were either dry or within a few weeks of drying off. As they freshened they were assigned to their respective groups and were started on the experimental rations.

Rations Fed

The rations fed to the several groups were identical except for the grain mixtures. They consisted of a fair grade of hay from mixed grasses (no legumes), good quality corn silage, dried beet pulp moistened with water before feeding, molasses mixed with the beet pulp at the rate of one pound per cow daily, and the grain allowance. A schedule of the grain mixtures is given in Table 2. Cornstarch was used in the urea mixtures to make good the deficiency in energy caused by purposely omitting from these mixtures the protein concentrates contained in the regular grain. Starch was the only readily available material which could be used which would not introduce some protein also.

TABLE 2. — FORMULAS OF GRAIN MIXTURES USED — POUNDS

Ingredient	Mixtures				Dry Cow Mixtures for		
	Regular	Urea No. 1	Urea No. 2	Control	Groups A & B	Group C	Group D
Hominy feed	600	400	600	660	...	600	600
Ground oats	400	400	600	600	300	300	300
Ground barley	...	...	...	...	...	300	300
Wheat bran	500	500	200	200	300	200	600
Corn gluten feed	200	200	...	...	...	...	...
Yellow corn meal	...	...	...	...	300	...	...
Linseed meal	...	...	...	..	100	...	200
Soybean meal	100	...	...		...	. .	...
Cottonseed meal	200	...	..	. .	...	...	. .
Cornstarch	...	460	540	540	...	550	. .
Urea	...	40	60	...	. .	50	...
Salt	20	20	20	20	20	20	20
Bone meal	...	20	40	40	...	40	. .
Vitamin A concentrate	5	5	5	5	...	5	5

Urea mixture No. 1, was used only for a short time at the beginning of the experiment in order to accustom the cows gradually to the change. It was followed by the No. 2 mixture which, with one slight modification, was continued for the duration of the work. The modification involved the substitution of 100 pounds of corn gluten feed for a like amount of cornstarch in July, 1940. During the latter part of the experiment cottonseed meal was omitted from the "regular" mixture because of its high price, and a like amount of soybean meal was substituted for it, so that the total amount of the latter was then 300 pounds per ton. The reason for omitting bone meal from some of the combinations was that they carried sufficient phosphorus without it. The vitamin A concentrate was omitted from the dry cow mixtures for groups A and B because these cows when dry received a roughage ration which, it was considered, carried adequate amounts of carotene. The control mixture, similar to urea No. 2 mixture except that it contained no urea, was fed at several intervals throughout the course of the experiment, for periods varying from a few weeks to seven months, to ten[3] cows in groups of from two to six cows at a time. This was done in an attempt to ascertain whether or not the basal ration minus urea would adequately support milk production; if not, then any difference between the performance of these cows and those getting the urea, or any improvement noted when urea was fed later to this control group, could presumably be credited to the effect of the urea.

---

[3] Four of these were in addition to the twenty-four included in the main part of the feeding trial. The others were a group of six composed of three each from Groups C & D, which were used for this phase of the work in a third lactation (1942), subsequent to the conclusion of the more comprehensive trials.

Additional data regarding the amounts of nitrogen and protein supplied by the various combinations, are given in Table 3.

TABLE 3. — LEVEL OF NITROGEN AND PROTEIN IN THE SEVERAL RATIONS

Grain Mixture	In the Grain Mixture			In the Total Ration		
	Nitrogen Percent	Protein Percent	Proportion of Total N Supplied by Urea	Nitrogen Percent	Protein Percent	Proportion of Total N Supplied by Urea
Regular	3.18	19.9	None	0.87	5.42	None
Urea No. 1	3.00	13.0	30.7	0.88	4.48	18.9
Urea No. 2	3.28	11.9	42.1	0.88	4.09	25.4
Control	1.90*	11.9*	None	0.68	4.26	None

*During the last few weeks that the control mixture was fed, its nitrogen and protein content were further reduced to 1.47 and 9.20 percent respectively. This reduction has been taken into account in calculating the percentages for the total ration.

RESULTS OF THE FEEDING TRIALS[4]

In evaluation of the results, consideration has been given to the following points:

1. Palatability of the rations.
2. General condition of the cows.
3. Changes in live weight.
4. Total milk production.
5. Shrinkage in milk flow.
6. Length of lactation and dry period.
7. Reproductive performance.
8. Level of urea in blood and milk.
9. Flavor of the milk.

TABLE 4. — RELATIVE AMOUNTS OF GRAIN CONSUMED

	Grain Consumed Daily Pounds		Extra Amount Consumed by Cows on Regular Grain
	Regular	Urea	
"Double Reversal" Groups			
1940	14.47	13.85	.62
1941	15.58	15.31	.27
"Continuous" Groups			
1940	12.48	12.41	.07
1941	11.51	11.54	−.03

Palatability of the Rations

The regular ration was in general somewhat more palatable than the ration which contained urea. This was particularly noticeable during the earlier stages of the work; as the cows became accustomed to the urea grain the difference in flavor of the regular ration became much less and finally disappeared almost entirely. Average daily grain consumption is shown in Table 4. Whether the urea mixture was less palatable because of the presence of the urea, or because of the relatively large amount of cornstarch used as a source of energy; or whether the regular mixture was more palatable because of the presence of such materials as cottonseed meal and soybean meal, remains an open question. If either of the last two reasons is the correct one, the difficulty could be readily overcome in feeding practice. It seems doubtful that the relatively small amount of urea present (3 percent as a maximum) could have had any substantial effect, either favorable or adverse, on palatability.

---

[4] Results from the so-called control group are treated separately in a later section of this bulletin.

TABLE 5. — AVERAGE GRADES* FOR GENERAL CONDITION OF COWS

	Regular Ration	Urea Ration
"Double Reversal" Groups		
At start	Good	Good + .50
During first year	Good + .31	Good − .06
During second year	Good + .42	Good + .50
"Continuous" Groups		
At start	Good + .25	Good + .25
During first year	Good + .30	Good − .08
During second year	Good + .36	Good − .09

*The numerical expression of the grade is based on a unit difference of 1.00 between one grade class and the next; thus, *very good* has been assigned a rank of 1, *good* a rank of 2, and so on down. In other words, "Good + .31" represents an average grade tending definitely toward *very good*, while "Good − .06" represents an average grade tending slightly towards *fair*.

General Condition of the Cows

All cows were graded for condition at the beginning of the experiment and twelve times during its course at intervals of two to three months. The data in Table 5 are based on 265 observations made jointly by the author and the farm manager at the hospital. Without exception, the condition of the cows on the regular ration tended to improve as the feeding trials progressed, while with one exception in the cows on urea the trend was in the other direction. This was especially true in the groups kept continuously on one type of ration and was evident to any but a casual observer. This may have been due not to the presence of urea, but to removal from the ration of some desirable conditioner when the cottonseed meal and soybean meal were purposely excluded. The grades were not based solely on condition as indicated by texture of hair and hide, but also on degree of fleshing. In the continuous groups, some of the cows on the urea ration were rather thin all through the trials, while those on the regular ration almost without exception maintained themselves in good to excellent flesh.

TABLE 6. — SUMMARY OF CHANGES IN LIVE WEIGHT

	Average Net Gain in Pounds per Cow	
	First Year	Second Year
"Double Reversal" Groups		
Regular ration	62	76
Urea ration	45	64
"Continuous" Groups		
Regular ration	239	274
Urea ration	229	266

The reason for the much larger net gains by the "continuous" groups is that they represent a much longer period; viz., from just after calving to just preceding the next calving. The interval for the "double reversal" groups was eight weeks in the first year and seven weeks in the second year.

Changes in Live Weight

Weights were taken on two consecutive days each month throughout the trials; the changes have been summarized in Table 6.

Although all the differences in weight favor the regular ration they are small and statistically not significant. However, of the sixty-four individual weight changes on which the average figures in Table 6 are based, four represented losses in weight, and all four of these losses were in cows in the double reversal groups while they were on the urea ration.

Total Milk Production

In the case of the "double reversal" groups comparisons are possible only between the several periods of the experimental lactations as the cows were alternated from one ration to the other. These data are summarized in Table 7. For the "continuous" groups comparisons are possible not only of their relative performance during the actual trial, but also with their performance previous to the start of the experiment. The data for these groups are therefore presented separately in Table 8. All yields reported have been adjusted for the following variables in the usual manner:

(a) Fat percentage of the milk.
(b) Length of lactation (305 days taken as the standard).
(c) Age of the cow.
(d) Length of time that next calf was carried during the lactation.

All of the cows were machine-milked three times a day. Accurate records of feed consumption as well as of milk production were kept at all times.

TABLE 7. — MILK PRODUCTION OF THE "DOUBLE REVERSAL" GROUPS

	Average Corrected Production (Pounds per Cow Daily)	Percent of Fat	Digestible Nutrients Required to Produce 100 Pounds of 4 Percent Milk	
			Nitrogen* (Pounds)	Total (Pounds)
Regular Ration				
First year..........	41.4	3.28	8.25	69.54
Second year........	43.2	3.26	8.38	66.68
Urea Ration				
First year..........	39.7	3.29	8.38	71.14
Second year........	41.1	3.16	8.56	69.80

The number of cow days was 784 in every case; i. e.,
Number in group (4) × days in week (7) × length of trial in weeks (28) = 784

*Expressed as nitrogen rather than as protein, since the nitrogen of urea cannot be reckoned on a protein basis.

Statistical analysis of the detailed data shows that none of the differences in average milk yield reported in Tables 7 and 8 are significant. It must be admitted, however, that the trend from year to year, not only in average yields but also in efficiency of feed utilization, is unmistakably in favor of those groups which received the regular ration. It will be observed also that although both groups dropped in production to about the same degree from 1939 to 1940, the subsequent increase in production from 1940 to 1941 was about seven times greater in the "regular" group than in the "urea" group.

TABLE 8. — MILK PRODUCTION OF THE "CONTINUOUS" GROUP

	Number of Cow Days	Average Corrected Production (Pounds per Cow Daily)	Percent of Fat	Digestible Nutrients Required to Produce 100 Pounds of 4 Percent Milk	
				Nitrogen* (Pounds)	Total (Pounds)
(a) Comparisons on Six Cows Only in Each Group**					
Regular Ration					
1939	1,808	42.34	3.33		
1940	1,491	36.13	3.35		
1941	1,744	42.61	3.34		
Urea Ration					
1939	1,879	44.37	3.33		
1940	1,511	38.11	3.39		
1941	1,714	39.06	3.25		
(b) Comparisons on All Eight Cows in Each Group					
Regular Ration					
1940	2,067	37.52	3.35	7.38	62.92
1941	2,330	42.22	3.32	7.00	62.62
Urea Ration					
1940	2,075	38.79	3.36	7.00	60.34
1941	2,345	40.36	3.24	7.44	66.54

*Expressed as nitrogen rather than as protein, since the nitrogen of urea cannot be reckoned on a protein basis.

**The 1939 records were made previous to the inauguration of this work, and are included here only for comparison. Although there were eight cows in each group during the entire trial, only six can be used for this comparison because two of the eight were first-calf heifers in 1940 and hence had no records in 1939. Also, because detailed feed consumption records were not kept prior to the beginning of the trials in 1940, no statement can be made in this part of the table regarding nutrients required to produce a given quantity of milk.

Shrinkage in Milk Flow

This criterion has been studied from two angles; (a) using the records from the "continuous" groups, the average percentage shrinkages from month to month in both years have been used to construct the graphs shown in Figure 1; in these graphs the individual monthly values have been fitted to a straight line by the method of least squares in order to bring out more clearly the trend of the data; (b) using the records from the "double reversal" groups the relative shrinkages in milk flow when the cows were shifted from one ration to another have been summarized in Table 9.

In the lactation immediately preceding the experiment (Fig. 1, 1939), the cows which later received urea for two years (Group C), maintained their persistency of milk flow at a somewhat higher level than did those cows which later received the regular ration (Group D). However, as the feeding trial progressed through 1940 and 1941 this superiority of Group C was progressively lessened, until at the end of the 1941 lactation the difference in favor of Group C was about one fourth of what it had been two years previously. Analysis of the data shows that none of the differences are significant but, as with actual production, the trend as the experiment progressed is very evident.

In the "double reversal" groups (Table 9), the shrinkages when the cows were shifted from the urea ration to the regular ration were consistently somewhat less than when they were shifted from the regular ration to urea. Although the differences probably are not significant, the trend is similar to that noted in the "continuous" groups; out of a total of thirty-two comparisons available, twenty-two were in favor of the regular ration.

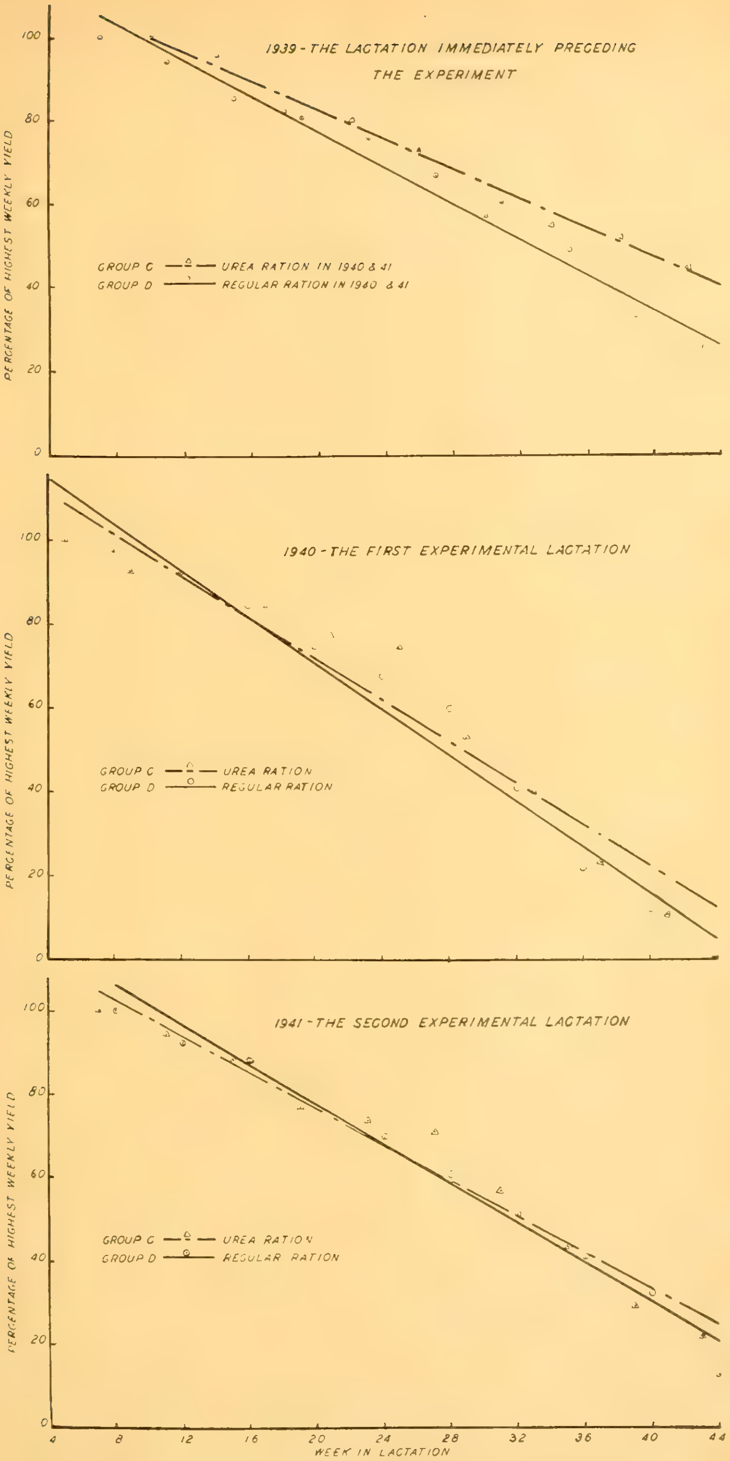


Figure 1. Weekly Shrinkage in Milk Flow — Percentage Basis.

TABLE 9. — SHRINKAGES FROM ONE PERIOD TO THE NEXT IN THE "DOUBLE REVERSAL" GROUPS *

Change	Average Percentage Shrinkage	
	In Milk	In Fat
From regular ratio to urea ration		
1940	18.7	19.1
1941	11.0	12.7
From urea ration to regular ration		
1940	9.7	9.9
1941	5.7	5.6

*The periods were eight weeks in 1940 and seven weeks in 1941.
The basis of comparison is the production for one entire period contrasted with the period immediately following it. Each average figure is based on eight individual values.

Length of Lactation and Dry Period

Obviously only the data from the "continuous" groups can be used in studying this phase of the results. These have been summarized in Table 10: in general lactation was shortened and dry period lengthened during the experimental program, but differences between the groups were not sufficient to be of any significance.

TABLE 10. — AVERAGE LENGTH OF LACTATION AND DRY PERIODS

	Lactation (Days)		Dry Period (Days)	
	8 Cows	6 Cows	8 Cows	6 Cows
Regular ration				
1939	-*	301	-*	61
1940	258	249	120	131
1941	291	286	86	82
Urea ration				
1939	-*	313	-*	71
1940	259	252	84	92
1941	293	291	105	120

*Two of the eight cows were first-calf heifers in 1940; hence had no record in 1939. In order to make the comparisons more accurate, the averages for the six cows carried along from 1939 are given for each year as well as the average for all eight.

Reproductive Performance

Here also only the records of the "continuous" groups can be used. The average results shown in Table 11 indicate such nearly identical performance as to be dismissed without further comment.

Urea in Blood and Milk

Urea determinations were made during the summer of 1941 in the blood and milk of all cows in the experiment: twice in the blood (in May and July), and once in the milk (in August). Average results appear in Table 12. Differences were slight, but on the whole the values were higher for the cows on the urea ration than for those not receiving urea, which is what would naturally be expected.

TABLE 11. — AVERAGE RFPRODUCTIVE PERFORMANCE OF THE "CONTINUOUS" GROUPS

	Days from Calving to Next Conception		Number of Services Required for Conception	Days Calf Was Carried while Cow Was Milking		Calves		
						Average Weight[1] at Birth		Vigor at Birth
	8 Cows	6 Cows	8 Cows	8 Cows	6 Cows	8 Cows	6 Cows	8 Cows
Regular Ration								
1939..........	-*	93	2.0	-*	210	-*	87	Normal
1940..........	106	102	1.5	157	151	100	98	Normal[2]
1941..........	96	87	1.6	196	199	102	102	Normal[3]
Average, 1940 & 41.	101	95	1.55	177	175	101	100	....
Urea Ration								
1930.....	-*	105	2.1	-*	208	-*	100	Normal
1940..........	74	78	1.5	185	174	101	104	Normal
1941..........	119	121	1.5	174	170	101	100	Normal[4]
Average, 1940 & 41	97	100	1.50	180	172	101	102	....

*Two of the eight cows were first-calf heifers in 1940; hence had no record in 1939, the year before the beginning of the experiment. The averages for the six cows are given for each year as well as the average for all eight.

[1] Corrected for sex ratio.

[2] One calf very weak at birth, posterior presentation; all others normal.

[3] One cow aborted in the 5th month; all others had normal calves.

[4] One calf born dead, two weeks premature; all others normal.

In addition to the above, one cow on the regular ration had a retained placenta in 1941.

TABLE 12. — CONCENTRATION OF UREA IN BLOOD AND MILK

	Urea—mgm. per 100 cc.		
	In Blood		In Milk
	May '41	July '41	
Regular Ration			
"Double Reversal" group..........................	27.8	23.5	25.9
"Continuous" group..............................	23.5	15.2	26.1
Average..	25.7	19.4	26.0
Urea Ration			
"Double Reversal "group..........................	25.7	25.7	25.9
"Continuous" group..............................	25.3	15.6	26.3
Average..	25.5	20.7	26.1

Values given in the literature range from 30 to 50 mgm. for blood and from 11 to 43 mgm. for milk.

Flavor of the Milk

The milk from all four groups of cows was scored for flavor on two occasions (June and September '41) by a qualified flavor expert who did not know the identity of the samples. Scoring was done twice on each lot of samples: the first time about eighteen hours after the samples had been taken and cooled, and the second time about twenty-four hours after the first. Average scores as shown in Table 13 indicate that flavor differences were either very slight or nonexistent.

TABLE 13. — AVERAGE MILK FLAVOR SCORES
(Based on a possible score of 25)

	June Samples		September Samples		Average
	1st Day	2d Day	1st Day	2d Day	
Regular Ration					
"Double Reversal" group	23.00	23.00	22.00	21.00	22.25
"Continuous" group	22.50	22.50	21.00	20.00	21.50
Urea Ration					
"Double Reversal" group	22.00	22.00	22.00	20.00	21.50
"Continuous" group	22.00	21.00	22.00	21.00	21.50

Results from the "Control" Ration

It has been noted (see p. 4 and Table 2), that a so-called control ration was fed to certain cows in the herd from time to time in the course of the experiment. This was done in order to be sure that the basal ration (i. e., the urea grain mixture minus the urea) was inadequate for sustained milk production.

Two cows not included in Groups A, B, C, or D were fed this control ration for a time soon after the commencement of the feeding trials in 1940, and two others for a somewhat longer time in 1941. The first two fell off very rapidly in milk production after being placed on the control ration, while the others managed to maintain what seemed like a fairly normal level of production. Because of these rather conflicting results, it was decided when the main experiment was concluded at the close of the 1941 lactation, to run a somewhat larger group on the control ration during 1942. Six cows were chosen, three each from Groups C and D, the so-called continuous groups, and were fed the control ration from soon after freshening time in the spring of 1942 until the middle of December.

Because of unforseen circumstances and difficulties, some of them a direct result of the war emergency, the results for the full seven months of this last phase of the work cannot be used in entirety. There is, however, a period of twenty weeks, extending from the thirteenth to the thirty-second week inclusive, of each cow's lactation, which is reasonably free of the above-mentioned vicissitudes and the production data from which are rather clear cut. They are graphically portrayed in Figure 2, in contrast with the records for these same cows for the same portion of their 1940 and 1941 lactations. It seems evident that the control ration was inadequate to support milk production at the level of the two previous lactations. This conclusion is derived not only from the somewhat lower production level (on either an actual or a percentage basis) in the 1942 lactation, but also from the marked flattening of the 1942 shrinkage curve from about the twenty-fourth week onward, a change which apparently contradicts the conclusion. The contradiction, however, is only apparent, for this change took place soon after the introduction into the ration of alfalfa silage. This move was not intentional — it was resorted to only because the cows, milking much longer on the control ration than had been anticipated, had consumed all the corn silage reserved for the experiment the previous spring, and it was a case of feed alfalfa silage or discontinue the trial prematurely. The result, however, is just as impressive as if it had been planned — the cows responded immediately to the additional protein in the alfalfa silage and pulled up to a level comparable with their performance in 1940 and 1941, thus demonstrating their need for more protein than the basal ration contained.

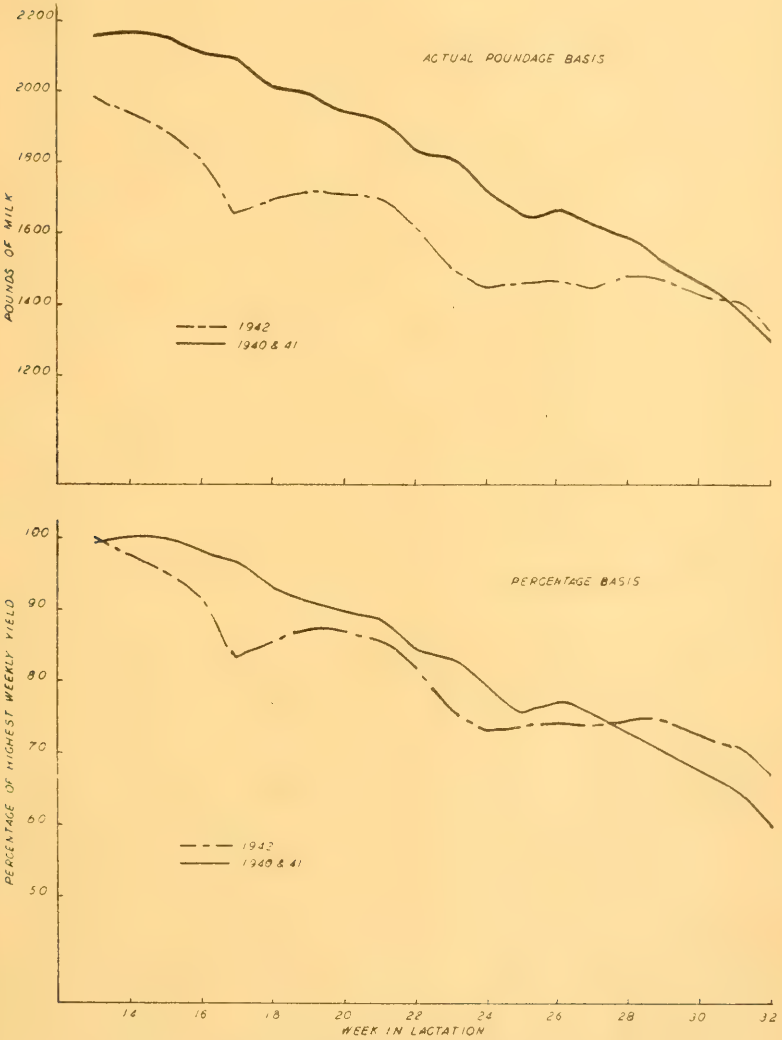


Figure 2. Weekly Shrinkage in Milk Flow.

The record of the six cows fed the "control" ration in 1942 compared with their record during the two years of the experiment.

In addition to this rather conclusive evidence on the inadequacy of the basal ration some further light is thrown by these later results on the main problem of urea utilization. It has been stated earlier in this section that three of the six cows on the control ration received urea continuously in 1940 and 1941 while the other three were on the regular ration. The relative performance of these two sub-groups on the control ration is shown in Figure 3. The rate of milk shrinkage was in general more rapid in those cows previously on urea than in those previously on the regular ration. The sharp upward trend of the curve from the 27th to the 29th week in group C, and from the 19th to the 20th week in group D, is due to the influence of the alfalfa silage. Group D was about two months behind the other in lactation, which accounts for the effect of the silage showing somewhat earlier in that particular graph. It should be noted here also that the addition of urea to the control ration for certain of the cows soon after the feeding of alfalfa silage had been discontinued, did not result in any such positive response as was noted with the silage. Possibly such a response was too much to hope for at this stage of lactation (the 28th week), but the fact remains that it was not in evidence.

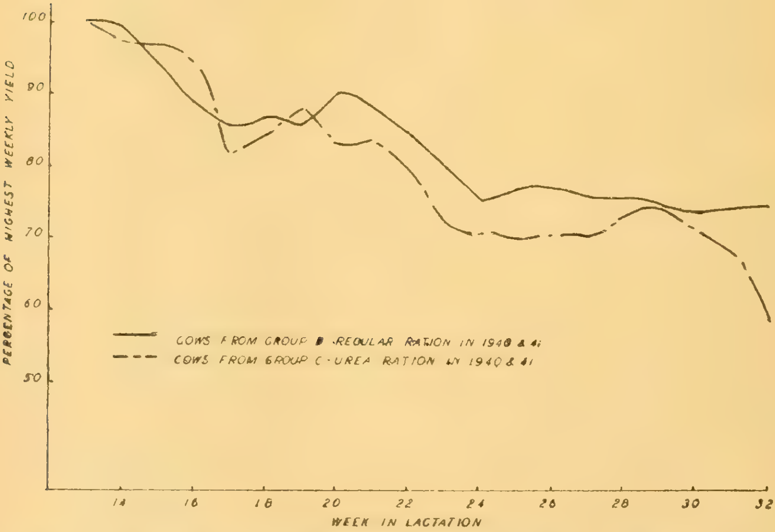


Figure 3. Weekly Shrinkage in Milk Flow on the Control Ration — Season of 1942. For comparison the six cows were divided into two groups on the basis of the ration fed during the two years of the experiment.

DISCUSSION

In consideration of the fact that the control ration was demonstrated to be inadequate for milk production, it seems clear that the urea must have been utilized to a considerable extent by the cows; otherwise their performance on the urea ration would have been similar to what it was on the control, since the only difference between the two was the presence (or absence) of urea. On the other hand the cumulative weight of small differences consistently in favor of the regular ration, would seem to indicate just as clearly that for maintenance and milk production the urea was not on a par with the standard protein concentrates contained in the regular ration. It seems appropriate to briefly recapitulate these differences.

The cows on the regular ration maintained their general condition somewhat better than those fed the urea ration; the trend in milk production and milk shrinkage favored the regular ration in both the "double reversal" and the "continuous" groups; and a group of cows that had been kept on the urea ration continuously for two years shrunk more rapidly in milk flow when placed on a control ration than a similar group that had been on the regular ration for the same period of time. The cumulative effect became more evident as the trial progressed, and illustrates rather clearly the inherent fallacy of drawing conclusions from short-time trials in this type of work.

It is recognized that the results of these trials are in some respects at variance with results obtained elsewhere in this country. Workers at the Wisconsin station have obtained results which indicate that urea can be satisfactorily substituted for linseed meal in the grain mixture for milking cows. On the whole, however, their results are not substantially different from those here reported and what differences there are may be due in part to the fact that these cows were on the average somewhat heavier producers, their average annual milk yield in the lactation immediately preceding the trial being in excess of 13,000 pounds.

Everything considered, it seems probable that urea will find a place in the feed trade as a partial protein substitute in grain mixtures for ruminants. It should be introduced with caution and its limitations duly recognized. The maximum amount fed should be not more than 3 percent of the grain mixture; it should be fed only to ruminants, i. e., to animals such as cows which have a multiple stomach; and it should be fed in conjunction with feeds which furnish liberal amounts of starch or other readily soluble carbohydrates. The reasons for these restrictions are twofold: first, the bacteria and other microorganisms which form protein from urea function on a worthwhile scale only in the paunch or first stomach of ruminants, and second, these organisms require a supply of readily fermentable carbohydrate in order to grow and multiply efficiently. Within these limits and assuming that a worthwhile tonnage can be released from its present use for explosives and fertilizer, urea can be of considerable aid in helping to relieve the present serious shortage of nitrogenous concentrates.

SUMMARY

Twenty-eight Holstein cows were used in a three-year trial to determine the adequacy of urea as a partial substitute for protein in milk production. The maximum amount of urea fed was 3 percent of the grain mixture; it supplied approximately 42 percent of the total nitrogen in the grain and 25 percent of the total nitrogen in the entire ration. It was compared with such standard protein concentrates as cottonseed meal, soybean oil meal, and corn gluten feed, by two systems of feeding trials, double reversal and continuous. A control ration containing no urea was fed to some of the cows as a check on the adequacy of the basal ration.

Results showed that considerable use was made of the urea, although it was not quite on a par for maintenance and milk production with the standard protein concentrates. With due recognition of its limitations, urea will undoubtedly find a place in the feed trade, especially in times of protein shortage such as we are now experiencing.

LITERATURE CITED

(1) Zuntz, N. Pflügers Arch. f. die Gesam. Physiol., 49, 477. 1891.

(2) Mitchell, H. H., and Hamilton, T. S. The Biochemistry of the Amino Acids. p. 588. The Chemical Catalog Co., New York. 1929.

(3) Krebs, K. Biedermann's Zentbl. f. Agr. Chem., Abt. B. Tierernährung, 9, 4-6, 394-507. 1937.

(4) Marston, H. R. Annual Review of Biochemistry, 8, 565. 1939.

Publication of this Document Approved by Commission on Administration and Finance
4M 7-43-12304.

5911 41

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

NOV 8 1943

BULLETIN NO. 407 JULY, 1943

Questions and Answers Concerning Pullorum Disease

By H. Van Roekel

The purpose of this bulletin is to make available for the Massachusetts poultry industry information which will aid the poultrymen to improve their methods of establishing and maintaining pullorum disease-free flocks.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

QUESTIONS AND ANSWERS CONCERNING PULLORUM DISEASE

By H. Van Roekel,[1] Chief of Laboratory,
Poultry Disease Control

INTRODUCTION

Pullorum disease is of great concern to the poultry industry. In order to assist the Massachusetts poultrymen in combating pullorum infection, this question and answer bulletin has been prepared, which deals with the practical aspects of the nature, eradication, and prevention of the disease.

HISTORY AND DISTRIBUTION OF THE DISEASE

1. **When was pullorum disease discovered?** This disease was first reported late in the nineteenth century. In 1899, Rettger isolated the causative organism from infected chicks. The organism was first named *Bacterium pullorum* and the disease was called bacillary white diarrhea. In 1925, the name of the organism was changed to *Salmonella pullorum*. In 1928, the name bacillary white diarrhea was changed to pullorum disease.

2. **What is the geographical distribution of the disease?** Reports of the disease have come to our attention from Africa, Asia, Australia, Canada, England, Continental Europe, South America, and every state in the United States. The disease is likely to exist wherever domestic poultry is raised.

NATURE AND DISSEMINATION OF THE DISEASE

3. **What is the cause of pullorum disease?** The cause is an infectious agent, a microscopic organism known as *Salmonella pullorum*.

4. **How does the disease affect mature birds?** In mature birds the disease usually appears in a chronic form. Infected birds as a rule can not be differentiated from the noninfected by physical examination. While the organism may localize in various parts of the body, it is most frequently found in the ovary. The organism has been recovered from the abdominal cysts, digital cushion of the foot, heart sac, intestinal contents, liver, lungs, nasal passages, ovary, remnant yolk stalk, spleen, tendon sheaths, and testicles. Localized infections may break down sometimes and liberate the organism into the blood stream, which may lead to death of the bird. This seems to occur particularly when some debilitating process is present. Infected mature birds suffer a higher death rate than do noninfected. Occasionally, sporadic outbreaks of an acute form are observed in flocks and the disease follows a definite course, accompanied by a high mortality.

5. **Can the disease spread among adult birds?** Yes. Noninfected mature birds may contract the disease when placed in direct or indirect contact with infected birds. The rate of spread is influenced by the condition of the flock and type of management, but generally speaking it appears to be slow. In acute outbreaks the infection may spread rapidly.

---

[1] Assisted by K. L. Bullis, O. S. Flint, and Miriam K. Clarke. Appreciation is extended to Dr. John B. Lentz, Head of the Department of Veterinary Science, for the suggestions made concerning this bulletin.

6. **Are male birds affected?** Yes. Males may contract the disease. The percentage of reactors among tested males is usually less than among tested females. In occasional flocks the percentage of reactors is greater among males than among females. It is probable that the sex difference is not the only factor responsible for the difference in the percentages of reactors.

7. **Do males play a role in dissemination?** Field observations suggest very strongly that the disease is transmitted by the male; although there is no conclusive evidence that males spread pullorum infection. Focal infections have been observed in the testicles. Also, one might assume that the infected male could eliminate the organism in the droppings, as occurs in diseased females. Furthermore, males might act as mechanical carriers in transmitting the organism from the cloaca of an infected female to the cloaca of a noninfected female.

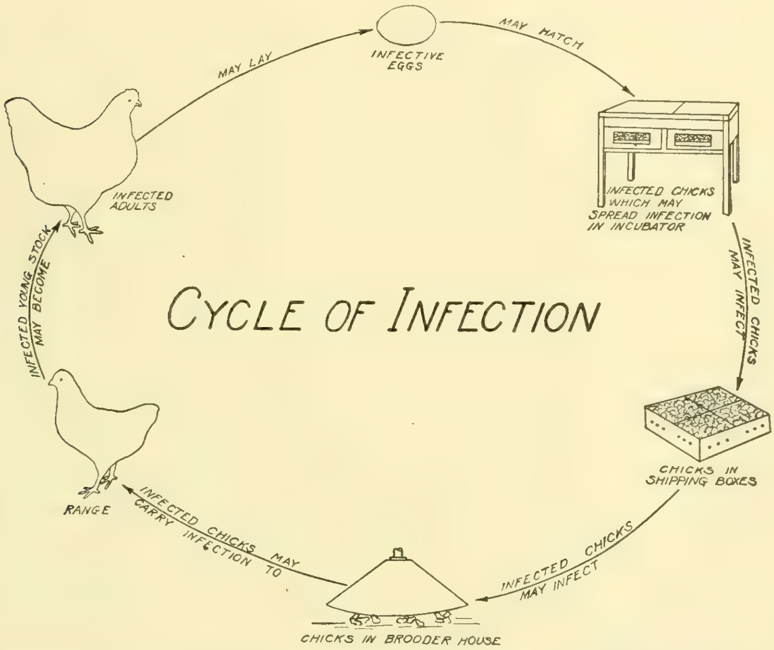

CYCLE OF INFECTION
MAY LAY
INFECTIVE EGGS
MAY HATCH
INFECTED CHICKS WHICH MAY SPREAD INFECTION IN INCUBATOR
INFECTED CHICKS MAY INFECT
CHICKS IN SHIPPING BOXES
INFECTED CHICKS MAY INFECT
CHICKS IN BROODER HOUSE
INFECTED CHICKS MAY CARRY INFECTION TO
RANGE
INFECTED YOUNG STOCK MAY BECOME
INFECTED ADULTS

Figure 1. Pullorum Disease Infection in a Flock May Follow This Cycle.
The disease can be eradicated either by breaking the cycle of infection through the elimination of the infected birds by means of the macroscopic agglutination test, or by disposing of the entire infected flock and replacing it with pullorum disease-free stock.

8. **What is a pullorum disease "carrier"?** A "carrier" is an infected bird that did not succumb to the disease during chickhood or became infected before or during maturity.

9. **How is the organism eliminated by adult birds?** The organism may be eliminated in the droppings (secretions and excretions from the digestive, urinary, and reproductive tracts), in eggs, through abrasions in the skin, and possibly from the mouth, nostrils, and eyes. The organism has been isolated from an abscess in the foot, which at one time appeared to have communicated with the exterior. The organism has also been found in the respiratory system. Apparently the organism is eliminated most frequently in eggs and droppings.

10. **Through what avenues may birds become infected?** Birds have been infected by way of the digestive and respiratory tracts, eyes, abrasions in the skin, and cloaca.

11. **How may infection be introduced into an adult flock?** The disease may be introduced into an adult flock through buying infected stock, returning birds from shows or contests, using contaminated buildings and ranges, using equipment (bird and egg crates, feed sacks, etc.) that may have been contaminated elsewhere, feeding infective eggs, and feeding garbage which might contain infective eggs or offal of infected birds.

12. **Can adult birds contract the disease by eating fresh eggs laid by infected hens?** Yes. Investigations have shown that birds may contract the disease by eating infective fresh eggs. In some flocks birds have formed a habit of egg-eating, perhaps as a result of birds laying the eggs on the floor or dropping board. At present the most important means of spread among adult flocks appears to be through eating infective fresh eggs.

13. **Can the disease be transmitted through the egg?** Yes. Infective eggs used for hatching purposes transmit the disease to the chicks. Feeding of fresh infective eggs to chicks or mature birds will infect them. Feeding of discarded infective incubator eggs to chicks or mature birds will readily infect them.

14. **How does the disease affect young chicks?** The disease may manifest itself within a few days after hatching. The following symptoms may be observed: depressed vigor, loss of appetite, a tendency to remain under the hover, frequent cheeping, droopy wings, shortened bodies, pasting of the vent with chalky excreta, marked depression and exhaustion followed by death. These symptoms are neither characteristic nor specific for pullorum disease alone, since they may be observed in other health disturbances of chicks. The mortality rate may vary from low to as high as 100 percent. Losses may be observed within two or three days after hatching and may continue until the chicks are three weeks of age or older. The greatest losses usually occur during the second week of chickhood. The onset and severity of the disease depend upon the amount of infection in the body, the ability of the organism to produce the disease, the resistance of the chick, and the care given by the poultryman. In some cases diseased chicks show little or no evidence of infection, while in other cases all the possible manifestations of the disease are found.

15. **Can the disease in young chicks be accurately diagnosed without bacteriological examination?** No. The symptoms and lesions are not specific of pullorum disease alone. Diagnosticians with considerable experience frequently may arrive at a tentative diagnosis of pullorum infection based on symptoms and lesions, which is later confirmed by bacteriological findings. As a routine procedure it appears necessary that all diagnoses of pullorum disease should be based on bacteriological evidence.

16. **Why is an accurate diagnosis important?** An accurate diagnosis will make it possible for the owner to follow proper eradication plans. An inaccurate diagnosis of pullorum disease may be responsible for unwarranted efforts and expenditures or cause further dissemination of the disease and delay eradication. One must recognize that for infected and noninfected flocks the plans of management should not be the same in order to obtain effective and profitable results.

17. **Where may chicks be sent for diagnosis?** Massachusetts flock owners may submit chicks to the Department of Veterinary Science, Massachusetts State College, Amherst, Mass.

18. **How should diseased chicks be submitted to the laboratory?** Five typical specimens affected with the disease, freshly killed and chilled (to retard decomposition), should be packed in a suitable container, well insulated, and placed in the mail so as to permit arrival in the shortest possible time. A complete history of the trouble (source and hatching date of chicks, age first observed sick, behavior of sick chicks, losses, and type of care given) should precede or accompany the specimens. Personal delivery of sick and dead chicks is preferable because it may avoid dissemination of the disease among chicks in transit and because more information can usually be obtained about the flock and a more satisfactory corrective program outlined.

19. **Does the disease spread among chicks?** Yes. The disease may spread among chicks in the incubator, chick box, and brooder. In the incubator the chick may be infected by inhaling or eating contaminated material. In the chick box and brooder the spread occurs largely through the digestive tract by eating or pecking contaminated droppings, litter, feed, and water.

20. **How may infection be introduced into the chick flock?** Purchasing infective eggs or stock, custom hatching for infected flocks, having eggs hatched where infection exists, feeding infective eggs, using contaminated equipment (sacks, chick boxes, egg crates, etc.), and permitting contact with infected adult stock, are all means of introducing infection into a chick flock.

21. **Can persons spread the disease?** Yes. The caretaker may spread the disease in handling and feeding the chicks. Contaminated droppings, litter, and feed may be carried from infected chicks to noninfected chicks. The possibility of a person carrying infection from one farm to another appears to be rather remote, unless he carries with him contaminated material which might be capable of infecting chicks. To safeguard against this it is advisable to prohibit visitors from entering the egg room, incubator room, and brooder houses.

22. **Are all birds equally susceptible?** No. Artificial exposures have shown that there is a variation in the degree of susceptibility to the disease among both chicks and adults.

23. **Do certain breeds appear to be less susceptible?** Opinion has been expressed that the lighter breeds appear to be less susceptible. However, heavy infection has been observed in flocks of all common breeds.

24. **Are fowl other than chickens susceptible?** Natural infection has been reported among turkeys, pheasants, guinea fowl, sparrows, bullfinch, goslings, and ducklings. Artificial infection has been produced in pheasants, guinea fowl, pigeons, canary birds, and sparrows.

25. **Are mammals susceptible to the disease?** Guinea pigs, mice, rats, cats, and especially rabbits are susceptible to artificial infection. Natural infection has been reported in foxes, mink, rabbits, and swine.

26. **Is a man susceptible to the disease?** The causative organism of pullorum disease has been isolated from a case of gastro-enteritis in man. Some investigators believe that the presence of *S. pullorum* in cases of gastro-enteritis in man is more prevalent than is commonly realized in view of the fact that the organism is not isolated from the feces as readily as other members of the Salmonella group.

LOSSES DUE TO PULLORUM DISEASE

27. **Do adult flocks suffer a mortality from this disease?** Yes. Occasionally a high mortality may be experienced when the disease develops into an acute form. Carriers in general do not possess the disease resistance of normal birds; therefore, a higher mortality is observed among carriers than among healthy individuals.

28. **Is egg production affected?** Yes. Investigations have shown that infected birds do not lay as well as noninfected birds. This may be accounted for by the diseased ovary, underdevelopment, and low disease resistance of the bird.

29. **Are fertility and hatchability affected?** Yes. The percentages of fertility and hatchability may be markedly reduced.

30. **Do chicks suffer a mortality?** Frequently high mortality, sometimes as high as 100 percent, is observed among infected chicks; infrequently little if any mortality is observed. Overheating, chilling, overcrowding, and insanitary conditions markedly influence the mortality rates.

31. **Do infected chicks mature normally?** In severe outbreaks the normal development is markedly affected, as shown by a lack of uniformity of growth and underdevelopment of birds. Chick flocks which have passed through an outbreak of pullorum disease should not be retained for breeding or egg production purposes.

32. **Does the presence of the disease affect the salability of eggs and stock?** Yes. The public has been and is being educated to buy only pullorum disease-free stock. A buyer who has had the unfortunate experience of buying and losing infected chicks will avoid repeating that experience if at all possible. A poultryman who has spent several years in developing a pullorum disease-free flock of good breeding, and then unthinkingly or unknowingly introduces infection, will suffer a great loss not only through the cost of eradicating the disease, but also from reduced sales.

CONTROL AND ERADICATION OF THE DISEASE

33. **Can the disease be eliminated by culling birds that lack vigor and vitality?** No. "Carriers" of the disease are not always the poorest individuals in the flock. Apparently normal, well-developed birds may be infected with the disease.

34. **Is incubator disinfection effective in eradicating the disease?** Incubator disinfection, while partially effective in decreasing the spread of the disease in the incubator, is not recommended as a means of controlling or eradicating the disease because it is unable to destroy the organisms in the live chick. Infected live chicks are spreaders of the disease, and complete control or eradication requires the elimination of the spreader. Therefore, poultrymen who have outlined an incubator disinfecting program with the intention of eradicating this disease, can expect but one result — failure. Incubator disinfection should be regarded as part of the general sanitary program and not as a disease eradication measure in itself.

35. **How may carriers of this disease be detected?** Infected birds may be detected by the following tests: Intradermal test; macroscopic tube agglutination test; rapid serum agglutination test; and whole blood agglutination test.

36. **What is the intradermal, pullorin, or "wattle" test?** This test consists of injecting a biological preparation into the skin of the wattle. If a swelling appears at the point of injection within a certain limit of time, the bird is regarded as infected.

37. **Is the intradermal test reliable in eradicating infection from a flock?** Leading investigators believe that the test in its present state is not so reliable as other tests which are employed for eradication of the disease.

38. **What is the macroscopic tube agglutination test?** In general this test consists of the following steps: all birds are legbanded; a small amount of blood is taken from the bird and the sample labeled with the legband number; a small portion of serum is removed from the blood sample to a tube containing turbid test fluid; the serum and test fluid are thoroughly mixed; the mixture is incubated for 24 hours or longer at body temperature; and the results are recorded at the end of the incubation period. A test is regarded as positive when a deposit has formed in the bottom of the tube leaving the test fluid partially or completely clear, and upon shaking of the tube the deposit breaks up into fine clumps. In a negative test the turbidity of the mixture is not changed. All birds whose samples react positively are reported as reactors or "carriers."

39. **What is the rapid serum agglutination test?** This test is a modification of the tube agglutination test. A small amount of serum taken from the blood sample is placed on a glass plate. To this serum is added a small amount of test fluid whose turbidity is far greater than that of the test fluid used for the tube method. The serum and test fluid are mixed by stirring and after a few minutes the result of the test is recorded. A test is positive when definite white clumps form in the mixture of serum and test fluid. In a negative test the mixture remains uniformly turbid.

40. **What is the whole blood agglutination test?** The whole blood agglutination test consists of mixing whole fresh blood or whole dry blood with a stained test fluid which is quite similar to that employed in the rapid serum method. The results are recorded within a few minutes after the blood and test fluid are mixed. A positive test is indicated by definite clumps floating in the mixture. A negative test shows no clumping. This test is used on the premises, usually in the poultry house, and tested birds are retained in trapnests or improvised retention coops until the results of the test are recorded. This makes it possible to remove positive birds from the flock immediately.

41. **Have any of these tests been adopted as standard?** At the present time, the macroscopic tube agglutination test is regarded as the standard test for detecting pullorum disease carriers. All three tests are recognized as official tests in the National Poultry Improvement Plan. However, for official certification of flocks as free of pullorum disease, only the macroscopic tube agglutination test should be accepted.

42. **Has a test been developed which has proved practical and reliable in the hands of poultrymen?** At the present time, no test for pullorum disease eradication is recognized as reliable and effective when placed in the hands of poultrymen or persons not properly trained. The different tests are of such a nature that they require thorough knowledge of the biological sciences in order to obtain most expeditious and successful results in eradication of the disease. The results of a test must be judged by the quality of the operator and the methods employed.

43. **What is a reactor?** A reactor is a bird whose serum gives a doubtful or positive reaction in the serum–test fluid dilution of 1–25 after 24 hours' incubation at body temperature. If only doubtful birds are found, they are subjected to further examination. Postmortem examinations are often helpful in making a diagnosis.

44. **Do infected birds always show a positive agglutination test?** Occasionally infected birds are discovered at necropsy that did not react positively to the agglutination test. The serum dilution (proportion of serum to test fluid) is an important factor in detecting such birds. The lower the dilution the more infected birds will react. Infrequently, birds may react at one test and not at the next. Such birds are called intermittent reactors.

45. **Are nonreacting infected birds considered as spreaders?** The causative organism has been found in eggs laid by such birds. The organism has also been isolated from the ovary and other organs on necropsy. Fortunately such birds are rare, as shown in flocks which are tested annually.

46. **Are all reactors infected with the organism?** No. The pullorum test may detect reactors which are infected with other organisms and not with the organism that causes pullorum disease. Birds affected with fowl typhoid react just as strongly with pullorum test fluid as do birds affected with pullorum disease. Infections with the paratyphoid organisms and the common colon bacillus in birds may at times cause reactions with the pullorum test fluid. Reacting birds also are observed in which no gross signs of disease can be found. Few such birds are found infected on bacteriological examination. A plausible explanation for failure to isolate the organism from some reacting birds is that such birds have been infected recently or that the organism has been eliminated recently. However, it must also be recognized that the methods of examination have their limitations.

47. **Do all reactors lay infective eggs?** No. If the infection is localized in those parts of the body which have no direct relation or communication with the oviduct, the organism is not eliminated through the egg. Furthermore, not all eggs laid by birds with infected ovaries contain the organism.

48. **Should fresh eggs from infected or untested flocks be fed to noninfected stock?** No. Investigations have shown that birds may be infected when fresh eggs laid by infected birds are fed.

49. **Why do negatively reacting birds suddenly become positive reactors?** Nonreacting birds that suddenly react positively, in all probability have been infected recently. Tests have shown that birds may react first between the fourth and seventh day after the first exposure to artificial infection. The avenue of infection, the size of dose, the ability of the organism to infect the bird, the resistance of the bird, and the ability of the bird to produce antibodies are factors which determine the reaction of the bird.

50. **Should the flock be tested annually?** Yes. Poultrymen who use part or all of their flocks for breeding purposes should test all birds on the premises each year. The test is a means of detecting infected birds. It does not assure the owner that once his flock is free from infection it will remain so. Table 1 shows that commercial flocks are vulnerable to infection even though they may have been negative for many years. In New England the amount of infection is small

in the majority of breaks. Through annual testing the infection is detected and eliminated before it has an opportunity to cause great losses. Therefore, annual testing is necessary to determine, from year to year, the status of the flock in regard to this disease.

TABLE 1. APPEARANCE OF PULLORUM INFECTION IN PREVIOUSLY NONREACTING FLOCKS*

(Classified according to number of consecutive years nonreacting)

Flock	No. of Years Negative	Flock Total	Number Tested	Positive Tests (Percent)	Explanation for Infection
1	3	5,105	123	2.44	Custom hatching
2	4	2,242	2,242	0.76	Unknown
3	4	1,300	1,280	0.16	Unknown
4	5	3,276	3,276	0.37	Unknown
5	5	3,114	3,114	0.29	Unknown
6	6	993	993	0.10	Unknown
7	6	4,271	4,271	0.09	Contact with untested stock
8	7	2,804	2,703	0.07	Unknown
9	7	2,483	2,481	0.04	Unknown
10	8	4,246	4,094	0.59	Questionable preventive measures
11	9	1,066	941	0.11	Custom hatching
12	10	6,260	6,260	0.06	Unknown
13	10	1,316	1,316	0.68	Unknown
14	14	880	880	1.02	Contact with untested stock
15	15	2,285	2,285	0.04	Returned birds from egg laying contests

*Refer to Questions 50 and 94.

51. **At what age may birds be tested?** Reactors have been detected among chicks as young as seven days of age. However, infected chicks do not all react at this age. Birds will show a larger percentage of reactors if tested between four and twelve weeks of age than if tested when younger. On the other hand, some young birds detected as reactors may become negative towards maturity. Since this disease will be disseminated as long as infected birds are present, the purpose should be to eliminate the majority if not all of the infected birds at the earliest practical age. Birds three to four months of age may be tested successfully. The National Poultry Improvement Plan stipulates that birds five months or older must be tested.

52. **Should birds attain egg production before they are tested?** It is advisable from an eradication point of view to eliminate the infected birds before they attain egg production in order to prevent the spread of the disease through the eating of infective eggs laid by diseased birds. Furthermore, elimination of infected birds at an early age will also prevent dissemination by other means common in a diseased flock.

53. **Can birds be tested on range?** Birds may be successfully tested on range provided suitable facilities are available. Range testing is recommended for infected flocks so that the bulk of the infection will not be moved into the laying quarters where the birds are more congested and there is greater opportunity for spread of the disease.

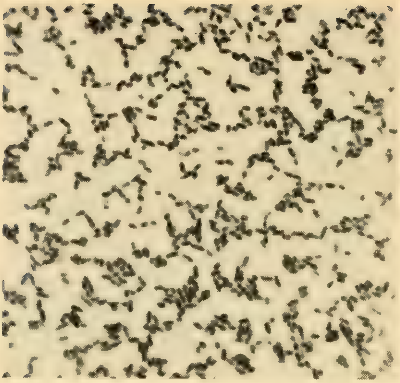


Figure 2. Salmonella pullorum, the Causative Organism of Pullorum Disease. Cells in a smear prepared from a 40-hour agar culture. × 1200. Refer to question 3.

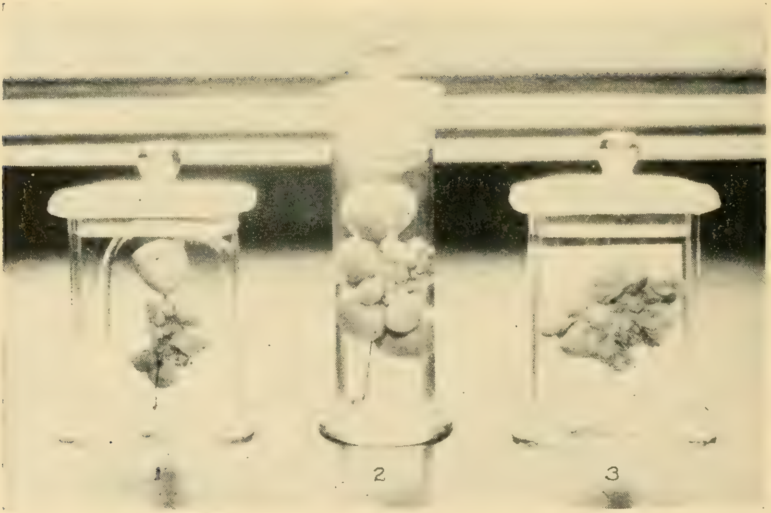


Figure 4. Ovaries Removed from Hens. Specimens I and III, showing irregular-shaped, discolored, and pedunculated ova, are affected with pullorum disease. Specimen II, showing normal ova, is not affected. Refer to question 4.

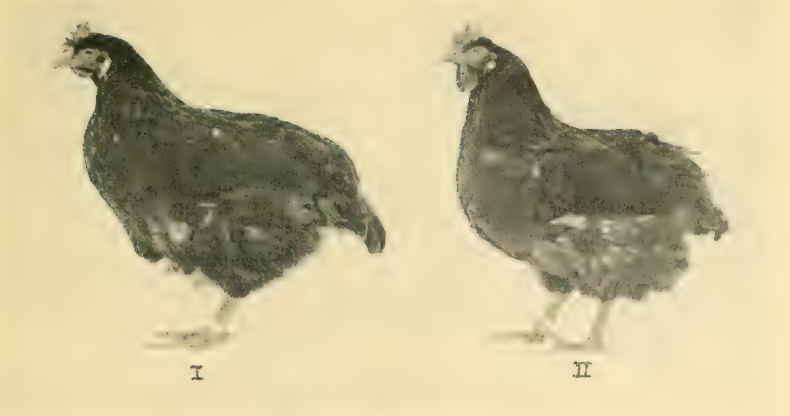


Figure 3. Bird No. I—Noninfected Hen; Bird No. II—Infected Hen.

Pullorum diseased birds as a rule cannot be differentiated from the noninfected by physical examination. Apparently normal, well-developed birds may be affected with the disease. Infection in such birds can be detected either by the agglutination test or by bacteriological examination. Refer to questions 4 and 33.

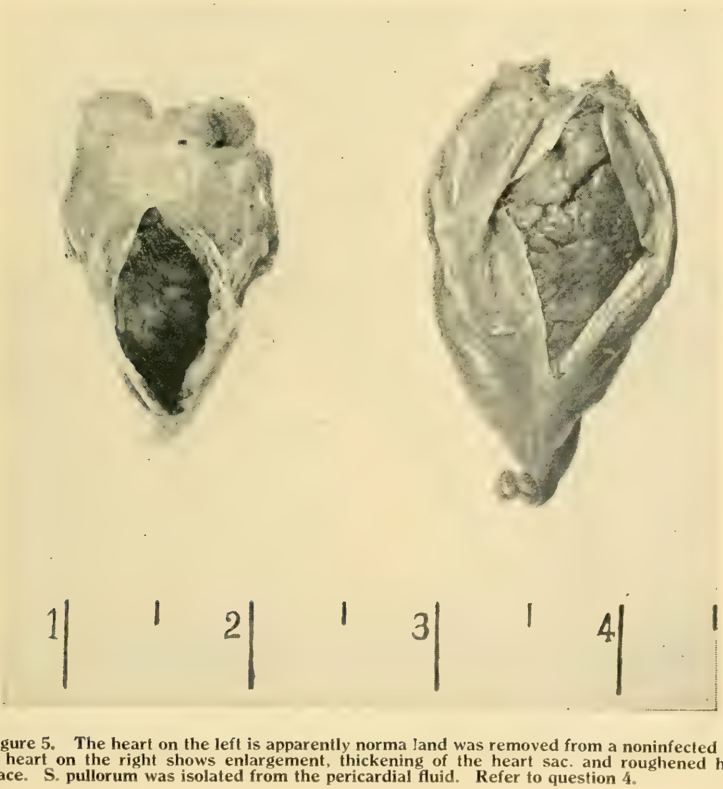


Figure 5. The heart on the left is apparently norma land was removed from a noninfected hen. The heart on the right shows enlargement, thickening of the heart sac. and roughened heart surface. S. pullorum was isolated from the pericardial fluid. Refer to question 4.

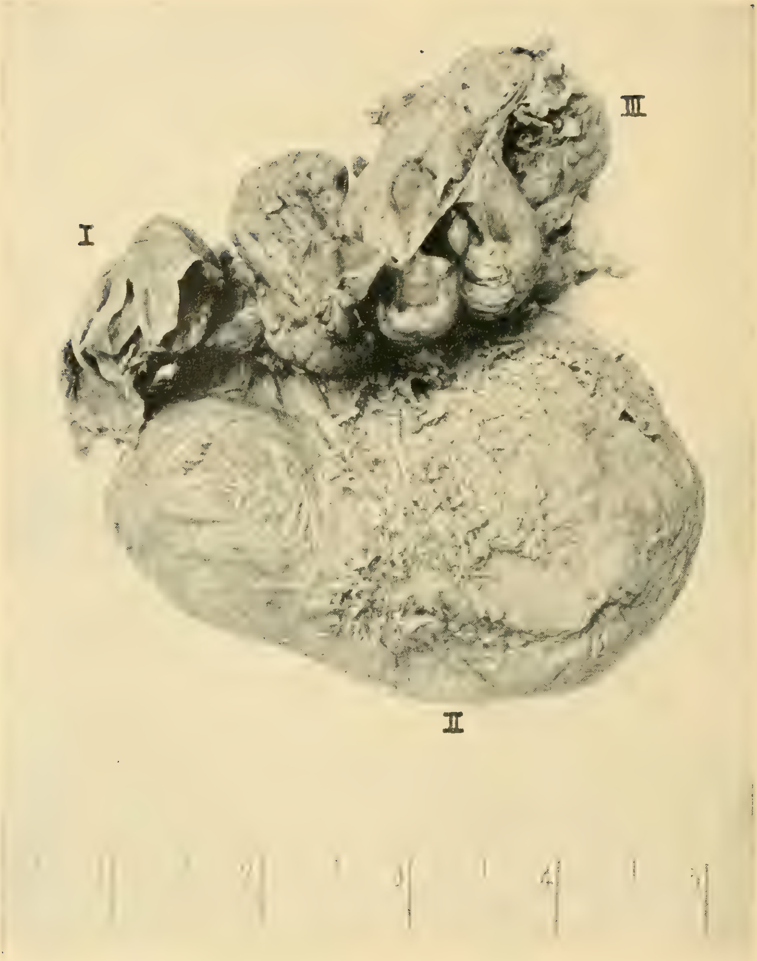


Figure 6. Oviduct Removed from an Infected Hen. Parts I and II are the funnel and albumen secreting portions of the oviduct, respectively. The funnel or fimbriated portion shows an enlarged and thickened wall. The albumen secreting portion (anterior end) is impacted with hard, dried egg material. The exterior surface of the impacted region is roughened due to inflammatory conditions. Such changes may be found occasionally as a result of inflammation of the oviduct and other abdominal organs. Part III is the shell gland portion. Refer to question 4.

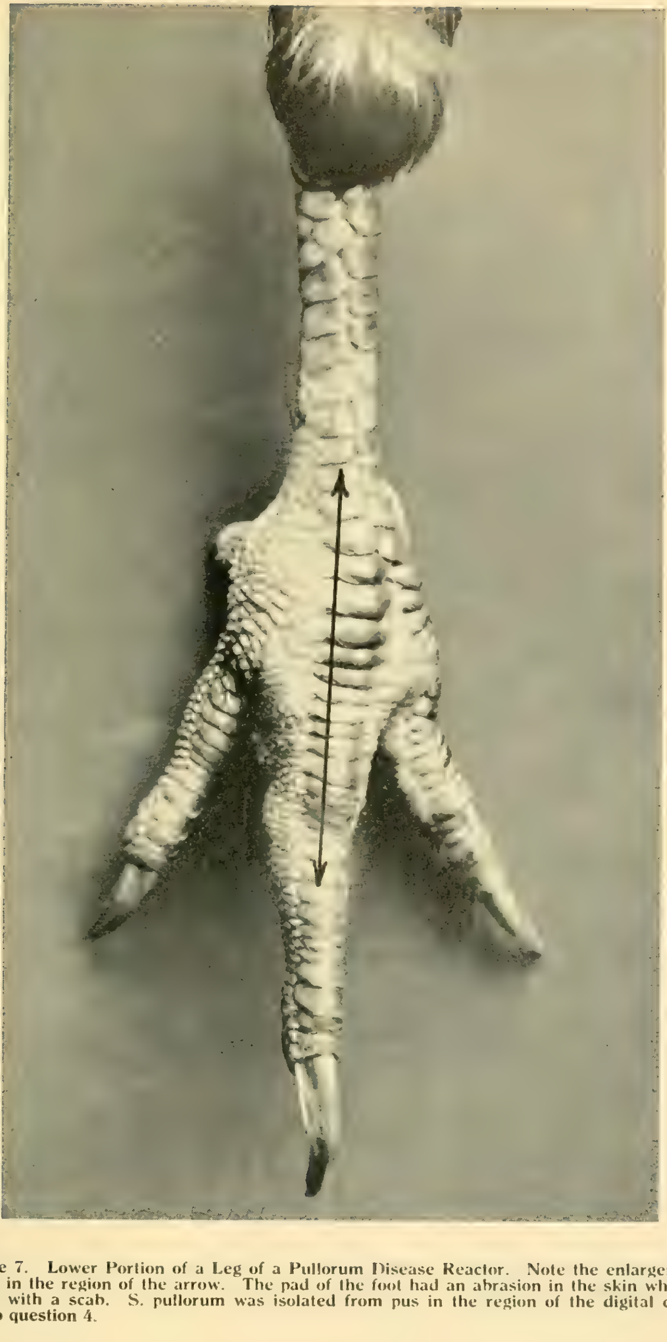


Figure 7. Lower Portion of a Leg of a Pullorum Disease Reactor. Note the enlargement of the foot in the region of the arrow. The pad of the foot had an abrasion in the skin which was covered with a scab. S. pullorum was isolated from pus in the region of the digital cushion. Refer to question 4.

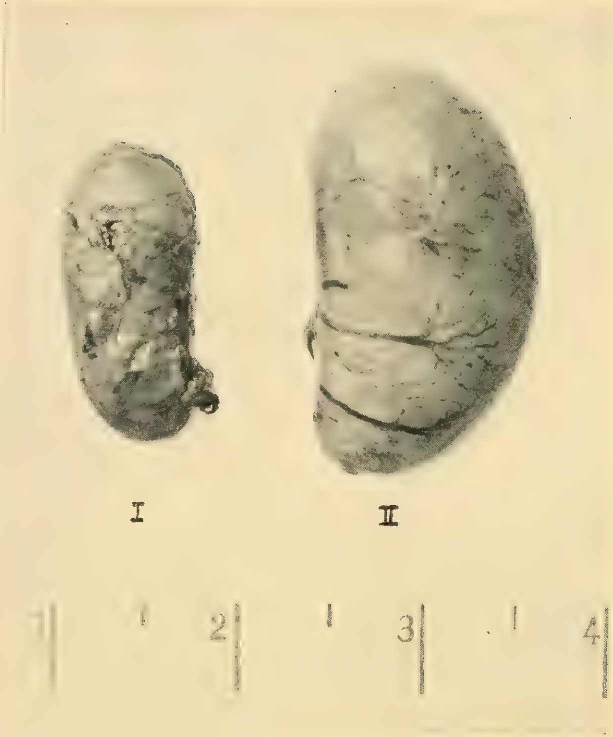


Figure 8. Testicles Removed from a Reacting Adult Male. Testicle No. I appeared to be functioning even though its structure was firm and its size greatly reduced. S. pullorum was isolated from this testicle. Testicle No. II appeared to be normal in size and texture. S. pullorum was not isolated from this organ. Refer to question 7.

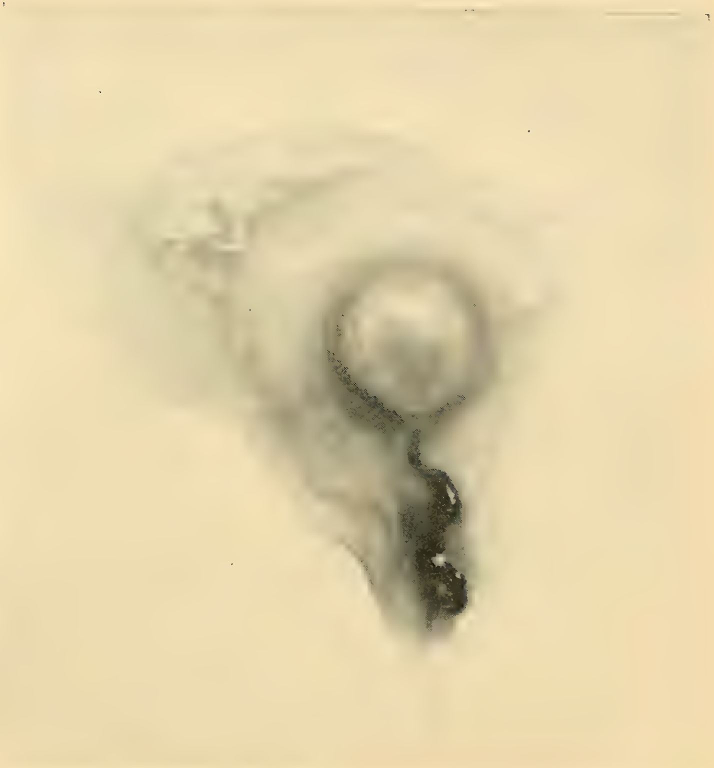


Figure 9. An ovum (abnormal in color, size, and shape) was found in an infertile egg which contained an apparently normal yolk. Note the dark peduncle which was its means of attachment to the ovary. S. pullorum was isolated from the amber colored, caseated contents of this ovum. Enlarged 2×. Refer to question 9.

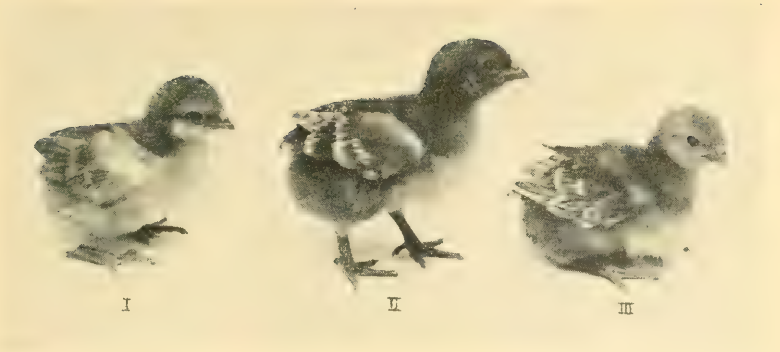


Figure 10. Nine-day-old Chicks Free of Pullorum Disease. Chicks I and II are males and III is a female. Refer to question 14.

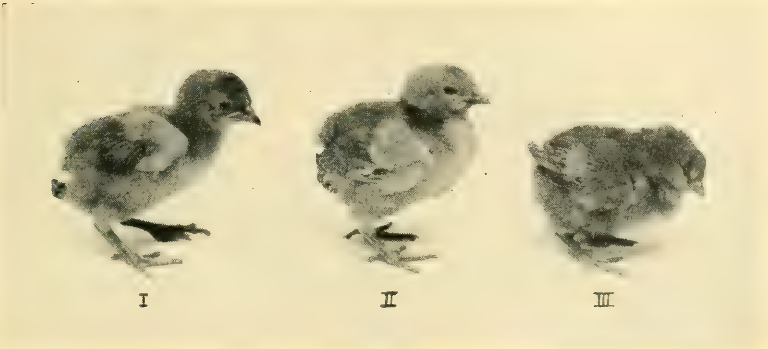


Figure 11. Nine-day-old, Naturally Infected Pullorum Diseased Chicks. Shortened bodies, pasting of the vents with excreta, droopiness and drowsiness are symptoms manifested by these chicks. Chick III died two days after it was photographed. S. pullorum was isolated from chicks II and III. Chicks I and II are males and III is a female. Refer to question 14.

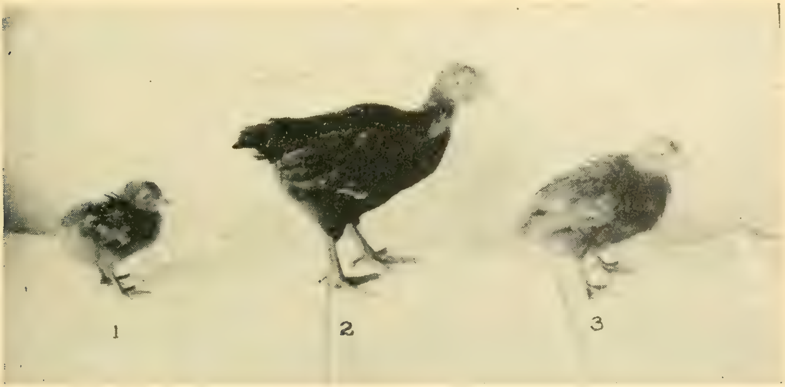


Figure 12. Six-weeks-old Chicks Exposed to Pullorum Infection When 72 Hours Old. Weights: No. 1, 115 grams; No. 2, 488 grams; No. 3, 193 grams. Pullorum disease has an influence on the rate, uniformity, and amount of growth. Refer to question 31.

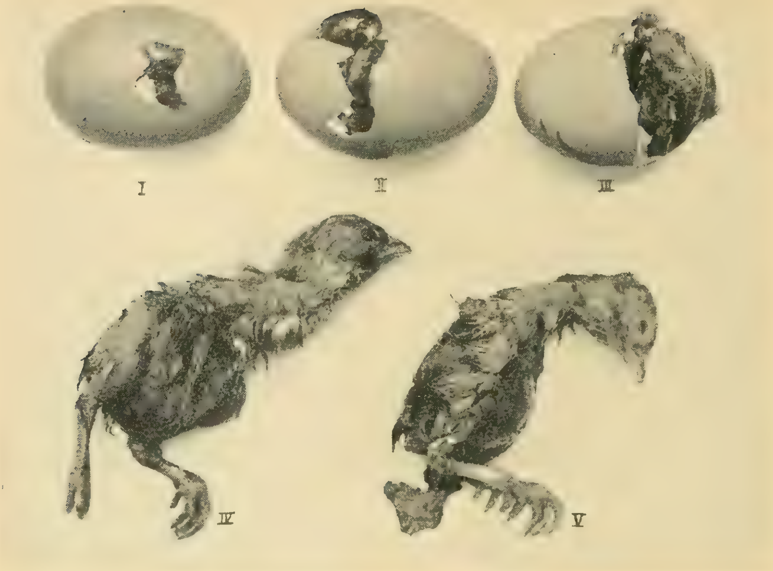


Figure 13. Dead Embryos. Pullorum disease affects hatchability. At the end of the incubation period, embryos may either be dead in the shell or be too weak to emerge from the shell. Embryos IV and V were removed from the shell on the twenty-first day of incubation. S. pullorum was isolated from embryos III, IV, and V. Pullorum disease should not, however, be regarded as the only cause responsible for low hatchability. Refer to question 29.

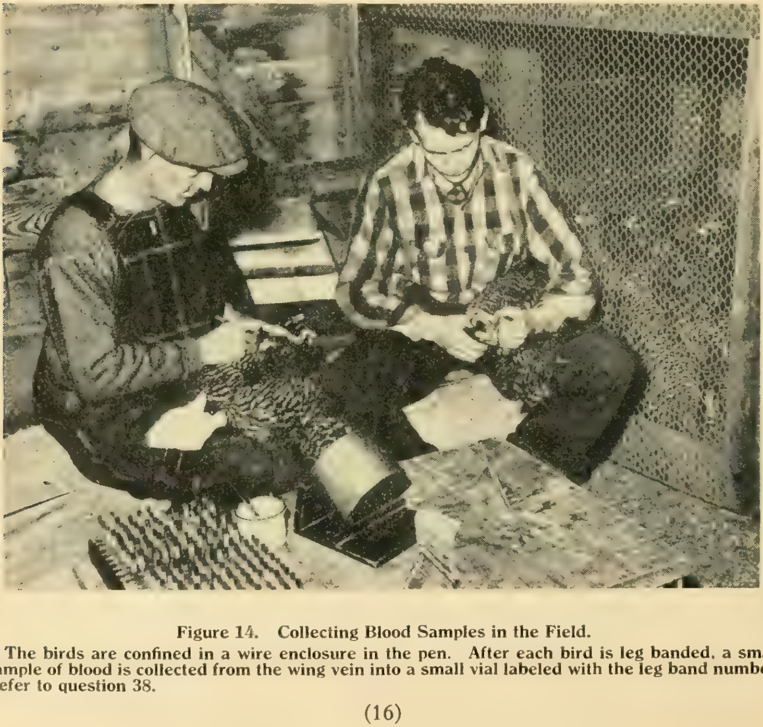


Figure 14. Collecting Blood Samples in the Field.

The birds are confined in a wire enclosure in the pen. After each bird is leg banded, a small sample of blood is collected from the wing vein into a small vial labeled with the leg band number. Refer to question 38.

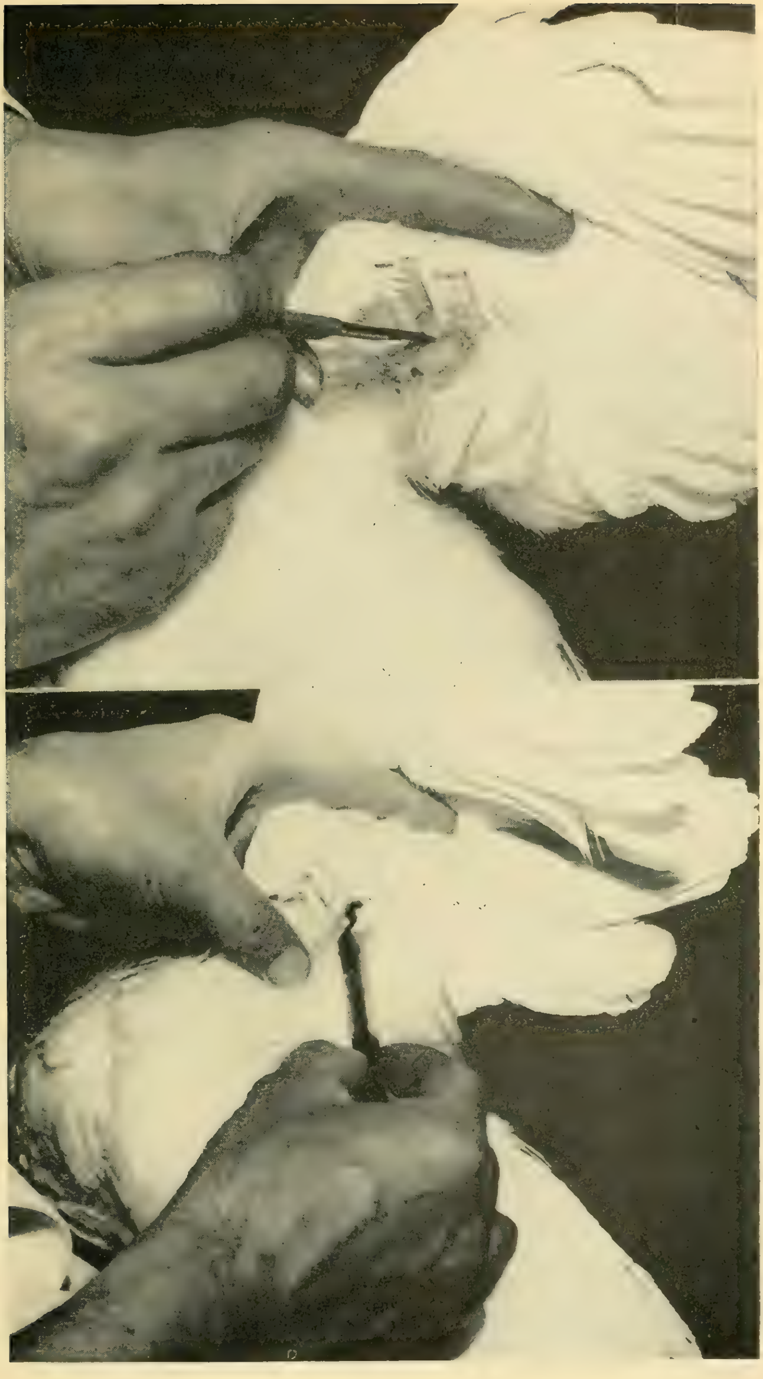


Figure 15. The wing vein is incised with a sharp pointed instrument (upper), after which the blood is collected into a numbered vial (lower). Refer to question 38.

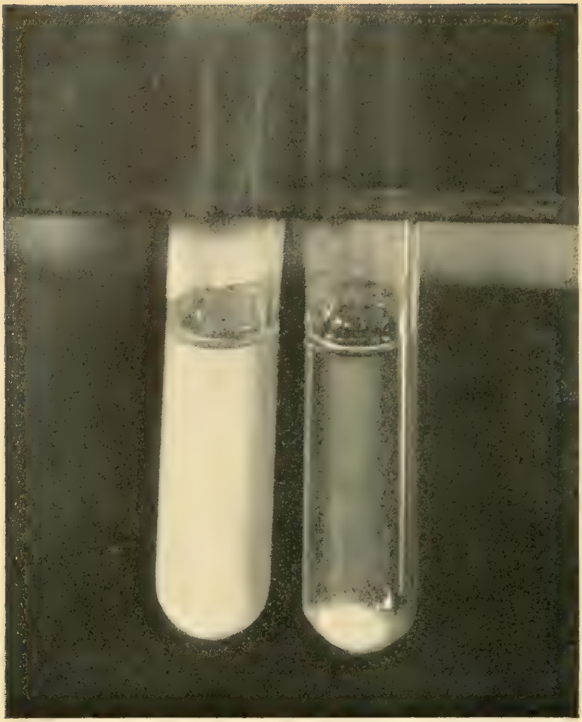


Figure 16. Macroscopic Tube Agglutination Test.

The tube on the left shows a negative reaction, and the tube on the right a positive reaction. Refer to question 38.

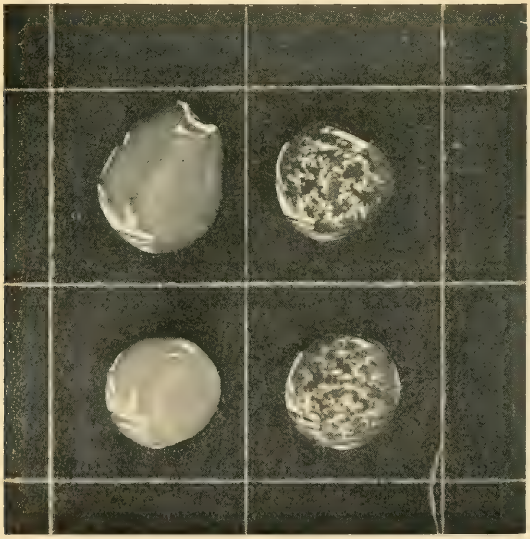


Figure 17. The Rapid Serum Agglutination Test.

The mixtures in the squares on the left show a negative reaction, and the mixtures in the squares on the right a positive reaction. Refer to question 39.

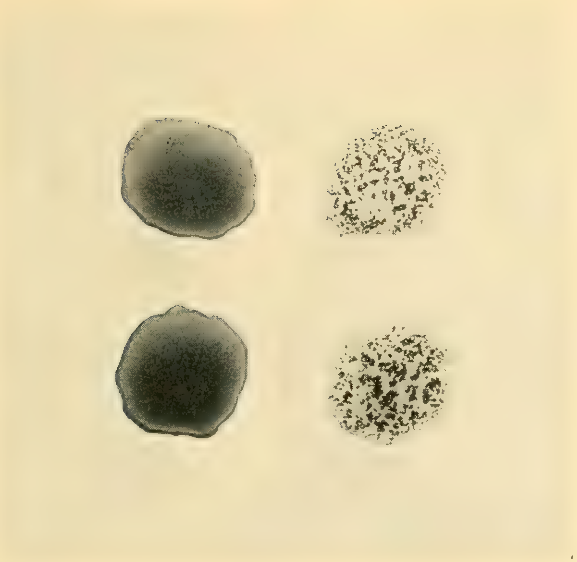


Figure 18. The Whole Blood Agglutination Test.
The mixtures in the squares on the left show a negative reaction, and the mixtures on the right a positive reaction. Refer to question 40.

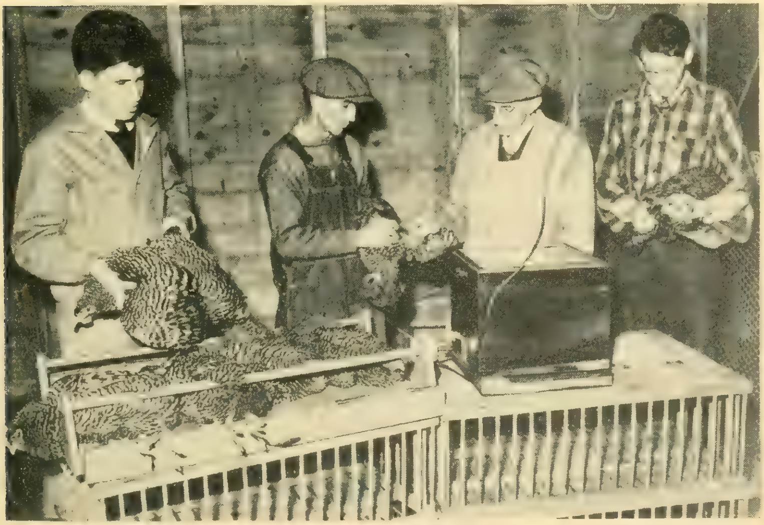


Figure 19. Testing of birds in the poultry house with the stained antigen whole blood test. Refer to question 40.

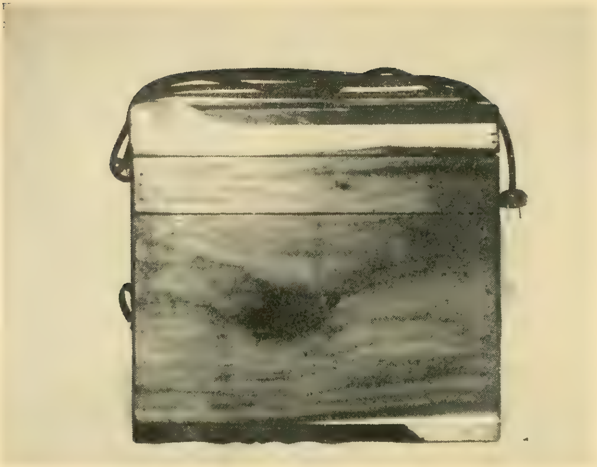


Figure 20. An Electrically Heated and Lighted Apparatus Used for the Whole Blood Agglutination Test.

Size 15 by 15 inches, by 14 inches deep. Construction consists of a wooden frame lined with Celotex and metal. Refer to question 40.

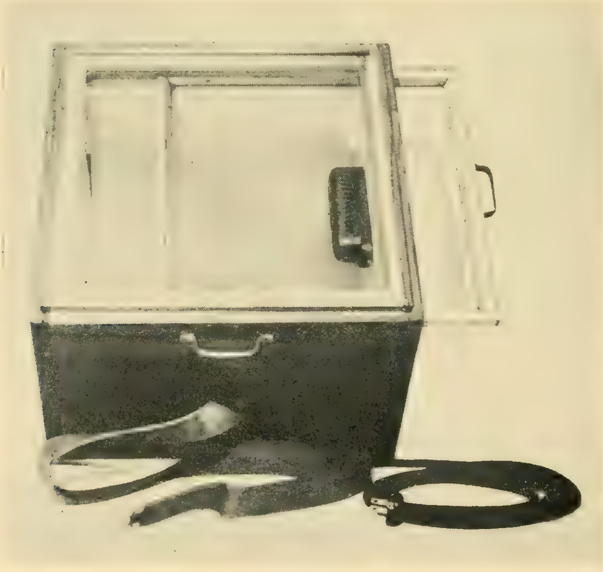


Figure 21. Same Apparatus with Cover Removed.

The test plate (size 12 by 12 inches) slides into a removable frame which is covered with glass. Refer to question 40.

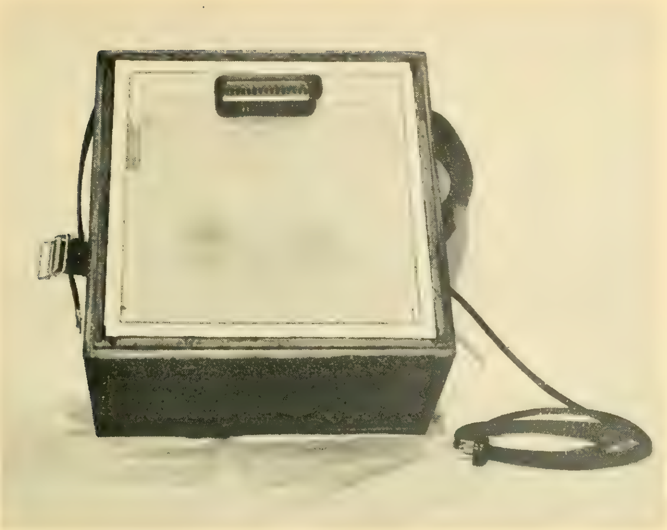


Figure 22. Same Apparatus as in Figure 21 with the Test Plate Holder Removed. The thermostat and frosted glass plate which rests on shoulders are exposed. The frosted glass permits uniform heat distribution. Refer to question 40.

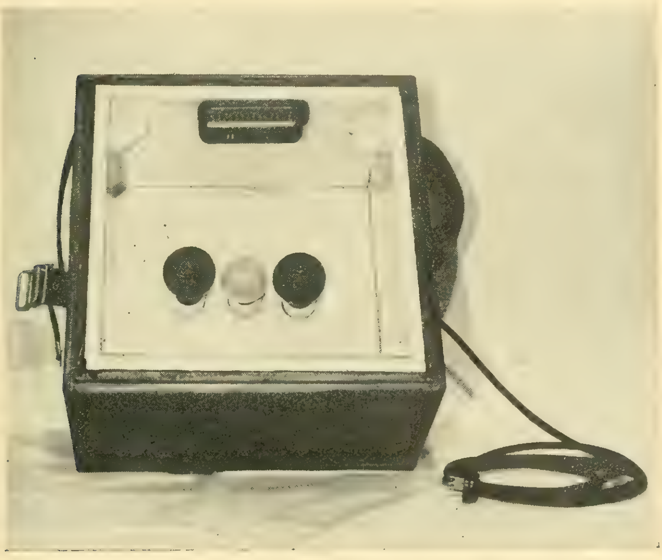


Figure 23. Same Apparatus as in Figure 22 with the Frosted Glass Plate Removed, exposing the two dark heat bulbs and the white light bulb. Refer to question 40.

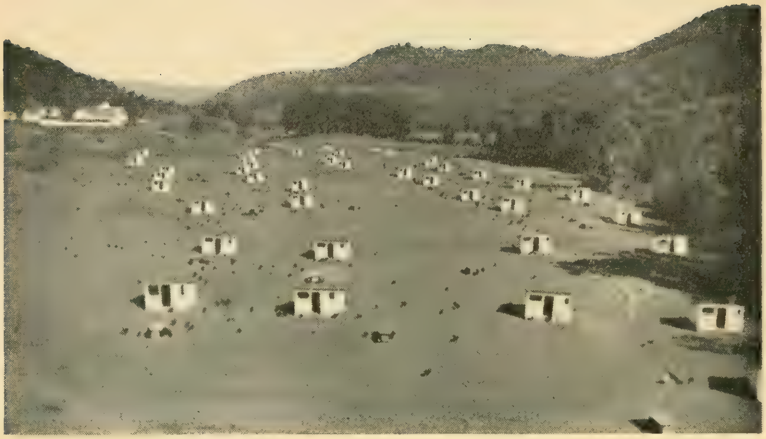


Figure 24. A modern poultry farm with ample range facilities for young birds, isolated from the laying quarters which house the adult hens. Cohabitation between young and old stock is avoided.

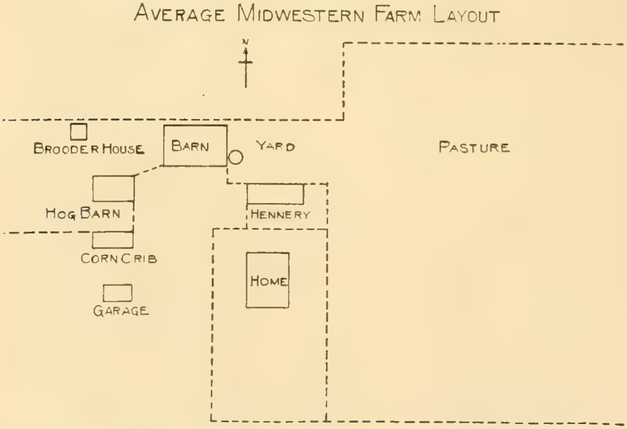

AVERAGE MIDWESTERN FARM LAYOUT
N
BROODER HOUSE
BARN
YARD
PASTURE
HOG BARN
HENNERY
CORN CRIB
HOME
GARAGE

Figure 25. A schematic illustration of a farm permitting cohabitation of young and old stock — a practice which perpetuates disease.

TURKEYS

Should turkey flocks be tested for pullorum disease? Yes. Turkey flocks used for breeding purposes should be tested annually because the infection behaves similarly to that in the chicken. Reacting turkeys should be removed promptly from the flock.

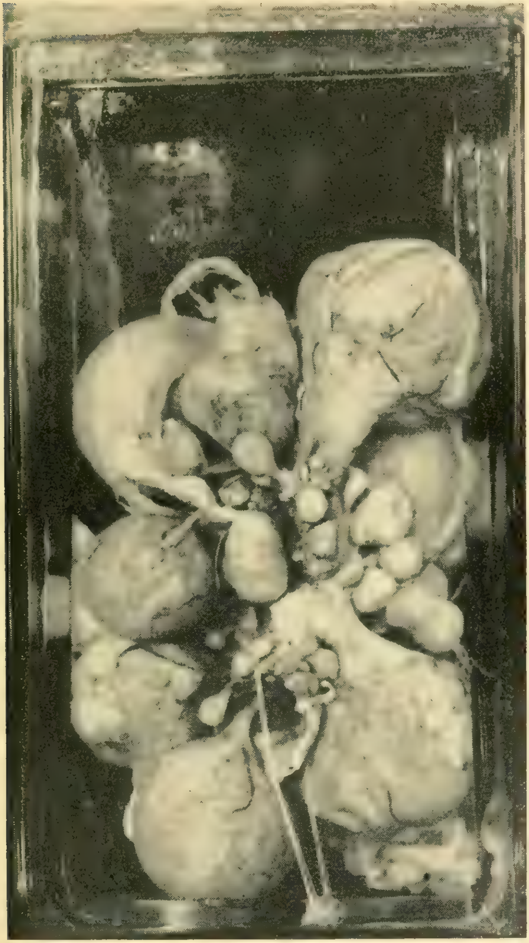


Figure 26
Ovary Obtained from a Reacting Turkey.
Numerous misshapen, discolored cystic ova and normal ova were present. Ovarian cultures yielded S. pullorum.

Is the whole blood test effective in detecting infected turkeys? No. Only the macroscopic tube agglutination method should be employed in testing turkeys for pullorum disease.

What serum antigen dilution should be used for diagnostic purposes? The 1:25 dilution has given the most satisfactory results. A low dilution is necessary in detecting infected turkeys, because their sera react only in very low dilutions. Low-dilution reactors are observed more frequently among infected turkeys than among infected chickens.

Are other measures besides testing necessary in establishing and maintaining pullorum-free turkey flocks? Yes. The measures listed under Question 94 are applicable to turkeys.

54. Is it necessary to test all birds on the premises? To determine the exact disease status of the entire flock, it is necessary to test all the birds on the premises.

55. Is it safe to retain a few untested culls on the premises for a short time after the test? Untested culls should always be regarded as dangerous to the tested flock even under the best of quarantine conditions. The safest procedure is either to cull and dispose of the undesirable birds before the test or to test all the birds on the premises.

56. Is it safe to retain untested birds in separate houses for egg and meat production? No. The practice of keeping untested birds on the premises for egg and meat production is one of the causes for failure to establish or maintain a pullorum disease-free flock. Most poultry plants are so organized and managed that no quarantine measures could be successfully executed on the two types of flocks.

57. Why should the entire flock be tested at one visit? Testing of the entire flock at one visit permits the flock owner and the blood collector to check more accurately whether all the birds have been tested. It prevents untested birds from mixing with the tested birds. It assures more economical and satisfactory routing of the blood collector. In a large testing program it may not always be possible to test the entire flock at one visit; but so-called "split-flock" testing should be kept at a minimum in order to facilitate the establishment and maintenance of pullorum-free flocks.

58. How should tested birds be marked? All tested birds should be banded with an official sealed band in order that their future identification may be accurately associated with their testing history.

59. Is retesting advisable in infected flocks? In retesting infected flocks one should take into account the value of the stock, the amount of infection, and the arrangement and mode of operation of the plant. The value of the stock is probably the primary consideration. If the value does not warrant the expenditure for retesting, then the inferior infected flock should be sold and replaced with pullorum disease-free stock. When the flock is heavily infected, retesting is usually not advisable because the size of the flock will be so reduced that a profitable breeding program can not be followed. Furthermore, the eradication of infection often appears to be more difficult in such cases than where the amount of infection is small. Sometimes the arrangement and operation of the plant are such that a retesting program can not be applied effectively. If the nature of the flock and condition of the plant do not warrant or permit effective retesting, then the flock should be replaced with pullorum disease-free stock.

60. How many tests are necessary to eradicate the disease from a flock? The number of tests required to eradicate the disease is influenced by the condition of the birds, the amount of infection, the condition and management of the plant, and the quality of the test. With one exception, five retests conducted at approximately four-week intervals within one season have been the maximum number necessary to eliminate the infection from a flock in Massachusetts. In the one instance 17 retests failed to eliminate the infection completely. In some flocks only two retests were necessary.

61. Should infected or reacting birds be culled as soon as detected? Yes. Infected or reacting birds should always be regarded as spreaders of the disease. Therefore, immediate culling and disposal of such birds is recommended.

TABLE 2. DATA SHOWING THAT SHORT INTERVAL RETESTING OF INFECTED FLOCKS IS EFFECTIVE IN ELIMINATING PULLORUM INFECTION*

Flock Number		First Test	Second Test	Third Test	Fourth Test	Fifth Test	Results of Subsequent Season
1	No. of birds tested	2,481	2,292				3,213
	Percent reactors	0.04	0.00				0.00
2	No. of birds tested	2,703	2,560				3,178
	Percent reactors	0.07	0.00				0.00
3	No. of birds tested	6,260	6,330				6,962
	Percent reactors	0.06	0.00				0.00
4	No. of birds tested	2,242	1,953				2,710
	Percent reactors	0.76	0.00				0.00
5	No. of birds tested	189	152	48			467
	Percent reactors	1.59	0.00	0.00			0.00
6	No. of birds tested	3,114	2,663	648			3,625
	Percent reactors	0.29	0.04	0.00			0.00
7	No. of birds tested	880	778	724	348		856
	Percent reactors	1.02	0.39	0.00	0.00		0.00
8	No. of birds tested	243	262	223	179		199
	Percent reactors	11.11	1.15	0.00	0.00		0.00
9	No. of birds tested	1,765	1,559	1,508	1,108	767	1,796
	Percent reactors	3.17	0.13	0.00	0.00	0.00	0.00
10	No. of birds tested	640	440	399	352	339	747
	Percent reactors	27.34	4.32	1.00	0.00	0 00	0.00

*Refer to Question 60.

62. **Why should reactors not be retained for egg production?** Reactors retained for egg production are a constant source of danger to the noninfected birds on the premises. There is always the possibility that the reactors may come in contact directly or indirectly with the noninfected birds. Eradication of the disease from the premises can not be accomplished as long as reactors or infected birds are retained on the premises.

63. **What disposition should be made of reactors?** Reactors should be sold only for slaughter. Offal and waste should be properly handled to prevent the spread of the disease.

64. **Where there are only a few reactors, is home slaughter objectionable?** Home slaughter may be practiced if the reactors are slaughtered immediately after being detected and if proper disposal is made of the waste and offal. However, the safest procedure is to sell the reactors to a slaughtering plant.

65. **Is it dangerous to feed offal from dressed birds to animals?** Feeding offal from dressed birds to animals is an unsound procedure because they may either become infected or act as mechanical carriers and in that manner disseminate the disease.

66. **What disposition should be made of dead adult birds, waste and offal, infertile and unhatched eggs, and dead chicks?** Such materials should be burned to destroy all forms of life. An incinerator of some sort should be considered a necessary fixture on each poultry plant. Burying is not recommended unless the material is placed so deep that it will not be disturbed and lead to further dissemination of the disease.

67. **Is it necessary to clean and disinfect premises after reactors are removed?** Thorough cleaning and disinfection of the houses following the removal of the reactors is a very important and necessary step in an effective eradication program. Thorough cleaning of all parts of the pen and its equipment is essential to eliminate and destroy the causative organism of pullorum disease. A reliable disinfectant should be applied generously after the thorough cleaning. In extreme low temperatures a liquid disinfectant may be employed if a vacant pen is maintained on the plant. It is unlikely that thorough cleaning and disinfection can be accomplished in a pen while it is occupied. The dirty litter should be disposed of in such a way that it will not serve as a source of infection to birds. The sanitary aspect of a poultry plant should not be neglected, as is too often the case.

68. **What disinfectant should be used?** Any of the "permitted" disinfectants approved by the United States Department of Agriculture are applicable for general disinfection of poultry houses and equipment. Poultrymen have access to the list of "permitted" disinfectants through their local county agents.

69. **Should owners of pullorum disease-free flocks practice custom hatching?** Pullorum infection is readily introduced into flocks or hatcheries through the practice of custom hatching if the eggs come from flocks which are untested, improperly tested, or known to be infected. Unless the owner is certain that his customers are supplying noninfective eggs, custom hatching is a disease hazard to his flock. Flock owners and hatcherymen too often fail to check the pullorum status of flocks from which eggs are selected for hatching.

70. **Should owners of infected or untested flocks practice custom hatching?** Investigators have shown that infection may spread in the incubator; therefore, in order to prevent the dissemination of the disease, the practice of selecting hatching eggs from an infected or untested flock must be condemned. The first consideration for such owners should be to establish a pullorum disease-free flock, which will be for the good of the industry as well as for their benefit.

71. **What dangers are associated with the practice of having eggs hatched away from the premises?** The owner who follows this practice subjects his flock to the same hazards as the owner who does custom hatching. In fact it may be a more dangerous practice because he has no control over customers supplying eggs to the same hatchery. A thorough investigation of the pullorum disease standing of the flocks and the business integrity of the customers should be made to assure the maximum elimination of hazards. However, even with the utmost care, one may introduce infection through this practice.

72. **Does custom hatching facilitate the establishment and maintenance of pullorum-free flocks?** Yes and No. If hatcherymen select eggs only from flocks officially recognized as pullorum-free, custom hatching should aid in the establishment and maintenance of pullorum-free flocks. However, if hatching eggs are selected from flocks of questionable status or known to be infected, no progress in the eradication of the disease is to be expected.

73. **Is it safe to buy chicks from a hatchery that selects hatching eggs from both infected and non-infected flocks?** No. Hatcherymen that select their hatching eggs from untested flocks, known infected flocks, and pullorum-free flocks can not produce chicks that can be considered free of pullorum infection. Regardless of how carefully the hatchery may be operated, as long as eggs from infected stock are selected for hatching there is danger that the disease may spread

to chicks that are hatched from eggs selected from pullorum-free flocks. In some sections many hatcherymen do not appreciate this fact.

74. If new stock is desired, what kind should be selected? In selecting new stock, the first consideration is health. Adults, chicks, and eggs should be selected that are free from infection. Such stock may be obtained from recognized pullorum disease-free flocks.

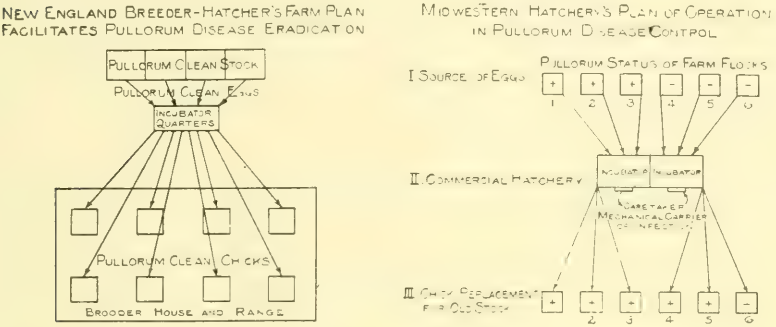

NEW ENGLAND BREEDER-HATCHER'S FARM PLAN FACILITATES PULLORUM DISEASE ERADICATION
PULLORUM CLEAN STOCK
PULLORUM CLEAN EGGS
INCUBATOR QUARTERS
PULLORUM CLEAN CHICKS
BROODER HOUSE AND RANGE
MIDWESTERN HATCHERY'S PLAN OF OPERATION IN PULLORUM DISEASE CONTROL
PULLORUM STATUS OF FARM FLOCKS
I SOURCE OF EGGS
+
+
+
-
-
-
1
2
3
4
5
6
II. COMMERCIAL HATCHERY
INCUBATOR
INCUBATOR
CARETAKER
MECHANICAL CARRIER OF INFECTION
III CHICK REPLACEMENT FOR OLD STOCK
+
+
+
+
+
-
2
3
4
5
6

Figure 27. Left: Schematic illustration of breeder-hatcher plant such as is common in the New England States. Pullorum-clean breeding stock, pullorum-clean eggs, and progeny all carefully managed by the owner, the breeder-hatcher.

Right: Schematic illustration of reproducing chicks in some sections of this Country. This hatchery selects eggs from various tested supply flocks, some negative and some positive, with the result that the negative supply flocks are replaced by infected progeny.

75. Are tested flocks officially classified? Yes. The National Poultry Improvement Plan has established four classes in pullorum control and eradication: U. S. Pullorum-Tested, U. S. Pullorum-Controlled, U. S. Pullorum-Passed, and U. S. Pullorum-Clean.

76. What is a U. S. Pullorum-Tested flock? A flock in which all chickens to be used as breeders have been tested for pullorum disease when more than five months of age, under the supervision of an official State agency. The percentages of tolerance of reactors specified in this grade are as follows: fewer than 9 percent in 1941-42, fewer than 8 percent in 1942-43, fewer than 7 percent in 1943-44, fewer than 6 percent in 1944-45, and fewer than 5 percent in 1945-46 and the following years. In each instance the last test must have been made within the 12 months immediately preceding the date of sale of hatching eggs or chicks from such flocks.

77. What is a U. S. Pullorum-Tested hatchery? One operating under the supervision of an official State agency and hatching eggs or brooding chicks from only U. S. Pullorum-Tested, U. S. Pullorum-Controlled, U. S. Pullorum-Passed, or U. S. Pullorum-Clean flocks; except that custom hatching for non-U. S. Pullorum-Tested flocks is permitted, provided certain stipulations as to the number and location of the incubators and the construction of the hatchery are observed.

78. What is a U. S. Pullorum-Controlled flock? A flock in which all chickens to be used as breeders have been tested for pullorum disease when more than five months of age, under the supervision of an official State agency, and which contains fewer than two percent of reactors, the last test having been made within 12 months immediately preceding the date of sale of hatching eggs or chicks from such a flock.

79. **What is a U. S. Pullorum-Controlled hatchery?** One operating under the supervision of an official State agency and hatching eggs or brooding chicks from only U. S. Pullorum-Controlled, U. S. Pullorum-Passed, or U. S. Pullorum-Clean flocks.

80. **What is a U. S. Pullorum-Passed flock?** A flock in which all birds on the premises have been tested for pullorum disease when more than five months of age, under the supervision of an official State agency, and which contains no reactors, the last test having been made within the testing year immediately preceding the date of sale of hatching eggs or chicks from such a flock.

81. **What is a U. S. Pullorum-Passed hatchery?** One operating under the supervision of an official State agency and hatching eggs or brooding chicks from U. S. Pullorum-Passed or U. S. Pullorum-Clean flocks only.

82. **What is a Pullorum-Clean flock?** A flock in which all chickens to be used as breeders have been tested for pullorum disease when more than five months of age, under the supervision of an official State agency, and which contained no reactors in two consecutive tests not less than six months apart, the last test having been made within the testing year immediately preceding the date of sale of hatching eggs or chicks from such a flock; provided the flock shall have met all the requirements of a U. S. Pullorum-Passed flock in the first one of these two consecutive tests. A flock developed exclusively from purchased hatching eggs produced by a U. S. Pullorum-Clean flock and hatched in a U. S. Pullorum-Clean hatchery may be recognized as a U. S. Pullorum-Clean flock in one annual test conducted under the supervision of an official State agency if no reactors are found.

83. **What is a U. S. Pullorum-Clean hatchery?** One operating under the supervision of an official State agency and hatching eggs or brooding chicks from U. S. Pullorum-Clean flocks only.

84. **Can pullorum-free stock be obtained from flocks or hatcheries classified in any one of the four grades with equal safety?** No. Any flock or hatchery which is permitted a tolerance of reactors, no matter how slight, is unsafe if pullorum-free stock is desired.

85. **Will stock from a flock with a low tolerance of reactors live as well as stock from pullorum-passed or pullorum-clean flocks?** No. If losses from pullorum disease are to be avoided, stock should be selected only from pullorum-free flocks and hatcheries.

86. **Who should be consulted in the purchase of pullorum disease-free stock?** Whoever is in the position to give reliable and official testing information regarding the flock or hatchery, aside from the owner. In Massachusetts, testing information can be obtained from the official State agency, the Massachusetts Department of Agriculture, State House, Boston, Mass.

87. **Why should buyers check advertisements?** Frequently claims in advertisements are incomplete, misleading, or false. The purchase of stock should not be based upon the claims in the advertisement without investigation.

88. **Do terms such as "tested stock," "100 percent clean," "state tested," "triple A" mean freedom from pullorum disease?** Such terms are indefinite and misleading in regard to the pullorum disease standing of a flock. The terms "tested stock" and "state tested" do not inform the reader about the particular disease and the results of the test. The term "100 percent clean" does not state the disease in question. The label "triple A" does not necessarily mean that the stock is free from pullorum infection. This miscellaneous terminology which is used loosely has misled the uninformed buyer. The terms alone do not have any meaning and cause considerable confusion. Therefore, one should investigate carefully the significance of such indefinite terms.

89. **Who can assist in determining the validity of the advertisement?** In Massachusetts, the State Department of Agriculture is able to assist in checking the validity of claims in advertisements. In other states, the official State agency should be consulted.

90. **Are the tested flocks in Massachusetts classified according to their pullorum disease status?** Flocks that have qualified for certain breeding and testing requirements are eligible for certification. The Massachusetts Department of Agriculture has established two grades of pullorum disease-free flocks: "Massachusetts Pullorum Passed" flocks are those in which all birds over five months of age have been tested and revealed no reactors; "Massachusetts Pullorum Clean" flocks are those in which no evidence of pullorum disease has been found by two consecutive approved agglutination tests, made of 100 percent of the poultry on the premises over five months of age, not less than six months apart, the last test having been made within the testing season immediately preceding date of sale of hatching eggs, baby chicks, or breeding stock from such flocks. Flocks are certified for one year only and in order to retain their official status, they must be 100 percent tested annually with no reactors. Copies of testing results of all tested flocks are submitted to the certifying agency by the testing laboratory. The two agencies operate independently.

91. **Where may information concerning official pullorum grades be obtained?** Inquiries concerning official pullorum grades should be submitted to the Massachusetts Department of Agriculture, State House, Boston, Massachusetts.

92. **How should tested flocks be classified as to their pullorum disease status?** Tested flocks in reality are either infected or pullorum disease-free. However, in a disease of this nature, it is not always safe to declare a flock free of the disease when only one negative test has been obtained. Therefore, two successive negative tests not less than six months or more than a year apart appear to be a safer index in determining the true status of a flock. Nevertheless, a flock which has passed one negative test should be given more recognition than a tested flock which has revealed reactors. The latter flock should be regarded as infected and unsafe for breeding purposes. Flocks in which a reactor tolerance is allowed should be considered unsafe for obtaining pullorum-free stock.

93. **Are other measures aside from the agglutination test important for successful eradication?** Yes. The agglutination test is only one step in an eradication program. Prompt removal of reactors and sanitary and preventive measures must be observed in establishing and maintaining a pullorum disease-free-flock.

94. What is necessary for successful eradication? Successful eradication is based upon the adoption of sound, effective, and uniform methods, properly and skillfully executed. A sound eradication program for the individual flock or for the poultry industry as a whole should include measures that will prevent the spread of the disease (through various channels as discussed in this bulletin) and permit effective eradication of the disease. The adoption of such methods is no more important than their proper execution. Control officials and poultrymen should not expect to attain their goal in eradication if the measures are not justly put into practice. Too frequently either delay or failure in eradication is due to faulty execution of recommended measures. The following measures should be observed in establishing and maintaining a pullorum disease-free flock:

(a) All the birds on the premises should be tested each year.

(b) If infection is present, the entire flock should be retested within four to six weeks until a negative report is obtained, provided the value of the birds justifies the expenditure.

(c) Every reactor, regardless of its value, should be removed from the premises and sold for slaughter immediately upon receipt of the report.

(d) Offal from all birds dressed for market or home consumption as well as dead birds that are not fit for consumption should be burned.

(e) The poultry houses, runs, and equipment, should be thoroughly cleaned and disinfected immediately after removal of reactors. An empty pen should be provided in each house to facilitate cleaning and disinfection during the winter months. Use disinfectants approved by the United States Department of Agriculture.

(f) Birds removed from the premises to egg-laying contests, exhibitions, etc., should be held in quarantine and determined free of disease before they are readmitted into the flock.

(g) Purchase of stock in the form of adults, chicks, and eggs should be from known pullorum disease-free flocks. Consult your county agent regarding additions or replacements in your flock.

(h) Eggs should not be saved for hatching until after a flock has been tested and all the infected birds removed. Early pullet testing will permit early hatching.

(i) Fresh and infertile eggs from unknown or infected sources should not be fed to chickens or exposed to animals such as crows, sparrows, and skunks that may carry or spread the infection.

(j) Poultrymen should not custom hatch for untested or infected flocks (including fowl other than chickens).

(k) Owners of pullorum disease-free flocks should not have hatching done where infected eggs or stock may be found.

(l) Poultrymen should not buy feed in bags that have been used or exposed to infection. (Such bags if properly disinfected will be safe for further use.)

(m) Poultrymen should regard fowl other than chickens as a possible source of pullorum infection unless tested and found free from pullorum disease.

(n) Poultrymen should not use equipment that has been exposed to or contaminated with infective material unless it is properly cleaned and sterilized or disinfected.

95. Why are sound, effective, and uniform methods of control and eradication necessary? Such methods are necessary to create faith and confidence in the eradication results upon which a profitable poultry industry rests.

96. Can reliable and uniform methods of eradication be instituted if poultrymen test their own flocks? No. At the present time, no simplified test has been discovered which can be placed in the hands of poultrymen and yet give reliable results. Uniformity of technique and interpretation of results would be sacrificed. The results of a test are no better than the ability and integrity of the person conducting the test.

97. When should new stock be tested and retained in quarantine before being admitted into the flock? In respect to pullorum disease, new stock received from doubtful sources should be retained in quarantine and pass two negative tests at least four weeks apart before being admitted to the flock. Frequently poultrymen fail to observe this measure and as a result introduce infection into their flocks. The purchase of new stock from doubtful sources is not recommended as a sound practice in poultry husbandry. Owners of flocks which are under official supervision should obtain approval from the official state agency regarding new stock.

98. Should birds employed for exhibition and contest purposes be returned to the premises? From the aspect of disease prevention, it is not advisable to return such birds to the flock. However, if for breeding purposes their return is really necessary, then they should be retained in quarantine and pass two negative tests at least four weeks apart before being admitted to the flock. Poultrymen attach too little significance to the introduction of disease through this channel.

99. Are any losses associated with testing due to bleeding and handling of birds? Very seldom birds die as a result of loss of blood. A decrease in egg production has been observed in some flocks. However, losses associated with the testing of birds should be negligible if the flock is healthy and properly handled.

100. Why is the flock owner requested to report the condition of his flock prior to the arrival of the blood collector? The flock owner is requested to report the condition of his flock in order to prevent the unnecessary exposure of the blood collector to disease outbreaks. Furthermore, the most important reason is to prevent the disturbance of diseased flocks, which is beneficial to the diseased and healthy birds. Delayed notification of the flock condition causes great inconvenience in routing the blood collector and consequently increases the cost of testing.

101. Is there danger of the blood collectors spreading the disease? Blood collectors are given instructions designed to prevent the spread of the disease from plant to plant. The field operations of the blood collector are checked from time to time by a laboratory representative. Flock owners are requested to report to the laboratory when blood collectors do not observe proper precautions.

102. What is the resistance of the causative organism to various environmental conditions? Investigators have reported that the organism may remain alive in artificially inoculated soil for approximately 14 months and in carcasses for at least 30 days. On dry cloth, retained at room temperature, it has remained alive for at least eight years. In chick feces it remained alive for approximately 101 days. It is easily destroyed by ordinary disinfectants, but its resistance to heating or exposure to sunlight is very slight.

103. Can medicines or drugs eradicate pullorum disease? No satisfactory medicine or drug has been found to be effective in eradicating or controlling the disease. Elimination of infected birds and proper follow-up measures must be resorted to in order to establish pullorum disease-free flocks.

104. Is Massachusetts making progress in eradication of pullorum disease? In 1919 under the Poultry Disease Law, an organized testing program was started and since then the following results have been obtained.

TWENTY-THREE-YEAR PULLORUM DISEASE TESTING SUMMARY

Season	Flocks	Birds	Total Tests	Positive Tests Percent	Non-reacting Flocks	Birds in Non-reacting Flocks	
						Number	Percent
1920-21	108	24,718	24,718	12.50	25	2,414	9.77
1921-22	110	29,875	29,875	12.65	27	4,032	13.50
1922-23	121	33,602	33,602	7.60	29	5,400	16.07
1923-24	139	59,635	59,635	6.53	38	11,082	18.58
1924-25	156	66,503	66,503	2.94	79	25,390	38.18
1925-26	201	67,919	67,919	2.31	124	33,615	49.49
1926-27	249	127,327	127,327	4.03	114	40,269	31.63
1927-28	321	190,658	232,091	6.52*	138	80,829	42.39
1928-29	413	254.512	304,092	4.25*	228	153,334	60.25
1929-30	460	331,314	386,098	2.17	309	203,038	66.97
1930-31	447	356,810	402,983	1.47	328	267,229	74.89
1931-32	455	377,191	420,861	0.90	355	298,534	79.15
1932-33	335	296,093	300,714	0.47	276	238,074	80.41
1933-34	262	263,241	284.848	0.53	229	212,782	80.83
1934-35	244	281,124	301,887	0.39	213	251,778	89.56
1935-36	252	329,659	344,081	0.30	230	315,215	95.95
1936-37	307	448,519	561,762	0.37	281	424,431	94.63
1937-38	308	480,227	497,769	0.17	286	457,466	95.26
1938-39	355	571,065	615,205	0.34	327	469,134	82.15
1939-40	346	573,000	673,222	0.51	332	497,356	86.80
1940-41	309	527,328	538,589	0.09	299	492,475	93.39
1941-42	366	653,080	662,715	0.27	350	591,628	90.59
1942-43	332	637,666	649,137	0.48	317	600,607	94.19

*Based on total birds tested: 1927-28, 190,658 birds; 1928-29, 254,512 birds.

The progress in pullorum-disease eradication in Massachusetts has depended to a great extent upon the cooperation of the poultrymen. If Massachusetts poultrymen expect to improve the standing of their flocks with respect to pullorum disease, they must adopt and conscientiously follow sound eradication and preventive measures.

105. Where may Massachusetts poultrymen obtain information regarding pullorum disease and testing service? Questions concerning pullorum disease and requests for testing service should be forwarded to —

Department of Veterinary Science
Massachusetts State College
Amherst, Mass.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

NOV 3 1943

Bulletin No. 408 — July, 1943

Home Refrigeration and Food Preservation

By

John E. W. McConnell, William B. Esselen, Jr.
and Carl R. Fellers

With proper use an efficient household refrigerator reduces danger of the development of food poisoning organisms to a minimum and effectively preserves the quality and vitamin content of foods.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

HOME REFRIGERATION AND FOOD PRESERVATION

By John E. W. McConnell, Research Assistant, William B. Esselen, Jr., Assistant Research Professor, and Carl R. Fellers, Professor, Department of Horticultural Manufactures

INTRODUCTION

The use of refrigeration for the preservation of foods has been known and practiced by man since the beginning of history. Food was often stored in caves, in containers immersed in flowing water, or in deep wells, where the temperature was 50°–60°F. even in warm weather. In hot climates water was kept comparatively cool by storing it in porous jars so that the evaporation of the water on the sides of the vessel cooled the contents.

More recently man learned to store ice, cut in the winter, for use throughout the summer months. The first ice box in America was set up in 1802, according to Moyer and Fittz (1932). However, only in very recent times has mechanical refrigeration been introduced with its accurate control over the storage temperature.

The importance of proper refrigeration can be appreciated when it is known that in 1929 an estimated 4 percent of the income of the average American home was wasted because of food spoilage which might have been prevented by proper refrigeration (Frigidaire Corp., 1929).

According to this same publication, the first mechanical ice-making machine was invented by Dr. William Cullen in England in 1775; while the forerunner of the modern mechanical refrigerator was invented in 1834 by Jacob Perkins, a Massachusetts engineer, who used ether as the refrigerant. The first commercial use of the invention was in 1855, when it was used to freeze ice, which in turn was used to refrigerate food. The automatic mechanical household refrigerator was first introduced about 1910. Since 1920 the adoption of these devices in homes has been so rapid that today there are over ten million units in use in the United States.

Most research in refrigeration has been done to safeguard the quality of foods during transportation, manufacture, commercial storage, or distribution. The major part of this work has been in the frozen food field where the holding temperature is around 0°F., and in cold storage where storage is for long periods of time. However, very little research has been conducted on the storage of foods in domestic refrigeratiors whch operate at a temperature of approximately 40°F. It would seem that this phase is of equal importance, as ordinarily much of our food is not used immediately after purchasing, but is stored until needed or as left-overs.

This investigation was carried out in an attempt to gather information on the effects of refrigeration on the nutritive value and keeping quality of various foods under normal household conditions. The effect of different relative humidities on left-over foods and odor and taste transfer in the ordinary household refrigerator were also studied.

REVIEW OF LITERATURE

A review of the literature reveals that comparatively little work has been published dealing directly with domestic refrigeration. However, a considerable amount of research has been carried on in the study of commercial cold storage conditions and frozen foods and some of these studies have been on the storage of foods at or near 40°F., the normal temperature of the household refrigerator.

Based on a survey of this available information the functions of home refrigeration in the preservation of food may be summarized as follows:

Vitamins Preserved by Refrigeration

Home refrigeration is very effective in preserving the vitamins in fresh and left-over foods. This is particularly true in the case of vitamins A and C. There is a rapid loss of these vitamins from fresh vegetables held at room temperature, but storage at refrigeration temperatures (approximately 40°F.) greatly retards this loss. Likewise the vitamins in left-over foods are well preserved by storage in the home refrigerator.

Optimum Conditions of Refrigeration

Good home refrigeration is dependent upon both temperature and humidity. The optimum temperature is considered to be 40°F. or below and in most cases a high humidity is recommended, especially in vegetable compartments. Low air movement in the refrigerator is important in preventing dehydration and flavor transfer. The use of covered refrigerator dishes preserves vitamins, and prevents dehydration and flavor transfer. However, meats should be stored uncovered and in the coldest part of the refrigerator to retard spoilage.

Refrigeration for Coffee

It is well known that coffee becomes stale very rapidly when stored at room temperatures. Recent work has shown that the rich aroma of fresh coffee is retained three times longer if the coffee is stored in a refrigerator rather than at room temperature.

Refrigeration Prevents Food Poisoning

When good foods are properly refrigerated in the home there is no danger of their causing food poisoning. If certain kinds of foods are held at room temperature for only a few hours there is danger that food poisoning bacteria may grow sufficiently to cause illness. The growth of these harmful bacteria is prevented and retarded at temperatures of 40°F.and below under normal conditions.

Cold a Good Preserving Agent

The storage life of perishable foods is greatly prolonged by proper refrigeration in the home because of the marked preserving effect of cold at temperatures of 40°F. or below.

What About Left-Over Foods?

Household refrigerators play one of their most important roles in the preservation of left-over foods. By this means a great economy can be realized by most families. This point is of particular importance during the National Emergency when it is so necessary that all foods be conserved and their nutritive value preserved in the best manner possible. The elimination of small-sized tin cans, owing to the tin shortage, means that small families must buy many of their canned foods in larger units than can be consumed at one meal. A marked economy can be realized by using the home refrigerator for the storage of these partially used cans of food.

Electric Refrigerators More Economical and Efficient

Investigators have shown that electric household refrigerators not only are more economical to operate but also provide a more efficient means of preserving foods than do ice-cooled refrigerators.

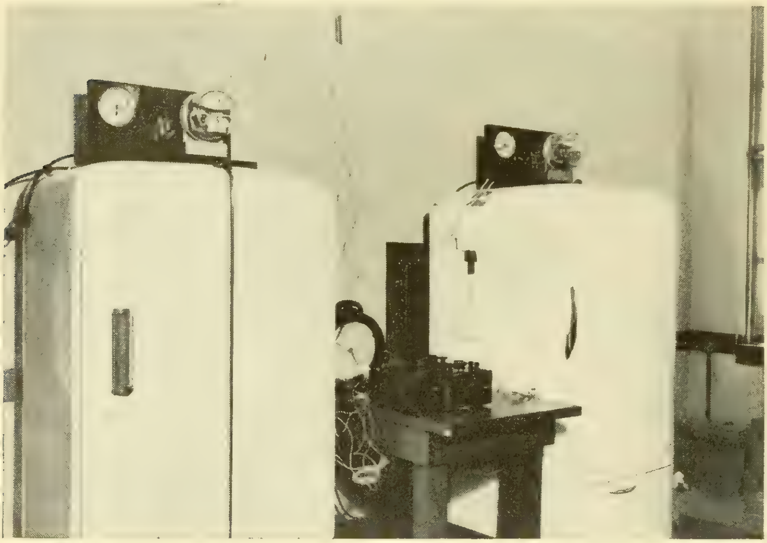


Figure 1. Arrangement of Refrigerators and Controls.

GENERAL EXPERIMENTAL PROCEDURE

Refrigerators

Two standard 1941 electric refrigerators were used throughout this investigation. One of the refrigerators had an eight cubic foot capacity and the other was a six cubic foot model. These two machines are shown in Figure 1, together with some of the equipment used to measure temperature and power consumption. They were set up in a room in which the temperature was kept as nearly constant as possible, varying only by about 10°F. during any one day. The temperature usually ran between 70°F. and 80°F.

Power Consumption

A watt hour meter and an electric time clock were connected in the circuit of each refrigerator so that the running time and watt hours of electricity consumed could be read. Thus the percentage of running time and power consumption could be calculated for each refrigerator in order to ascertain that they were functioning properly.

Temperature

Recording thermometers were used to record the changes in temperature both in the room and in the refrigerator cabinets. Thermocouples were also used to measure the temperature at different locations within the refrigerators and in the room.

For room temperature measurements, thermocouples were set eight feet, four feet, and ten inches above the floor between the two refrigerators. For the determination of temperatures in the refrigerator, a thermocouple was placed in the center and about two inches above each shelf; two other thermocouples were placed in the lower chamber of the freezing compartments, one centered on the back wall, the other suspended one inch from the roof directly in the center of the chamber; two additional thermocouples were placed in the freezing compartment to be inserted in the frozen food cartons placed therein.

The evaporator (freezing coils) temperatures were measured by means of special thermocouples, the junctures of which were soldered to small flat copper plates so that the thermocouple could be placed directly in contact with the surface of the coils. These were placed on the top and bottom coils of the freezing compartment.

All thermocouples were connected to a selector switch which in turn was connected to a potentiometer. The potentiometer was checked against a standard mercury thermometer before readings were taken.

Humidity

Different degrees of relative humidity within the refrigerators were obtained by the use of closed containers and by varying the refrigerator loads and door openings. The relative humidity measurements were made by means of wet bulb thermocouples which consisted of thermocouples wound with a wick of unbleached linen and mounted, together with a well, on small stands. The wet bulbs were standardized by means of a sling psychrometer at room temperature to within 1°F. and the correction taken. At least three of these thermocouples were used in each refrigerator and the lowest readings were employed. When a wet bulb appeared to be "off" it was removed from the cabinet, checked with a sling psychrometer and rewound, if necessary.

Relative humidity readings were made at the beginning and end of at least two consecutive periods when the refrigerator motor was in operation, and the mean temperature and humidity calculated. The readings were made after the refrigerator doors had not been opened for at least six hours so that the cabinet had had time to reach a constant temperature.

Dehydration

Loss of moisture was determined by weighing the samples directly, in their containers, to the nearest tenth of a gram. The amount of dehydration of the foods themselves, in the tests on "left-overs", was ascertained by the change in moisture content. Moisture determinations were made by drying the samples at 135°C. in an electric air oven, according to the A. O. A. C. (1940) method.

Determination of pH Value

The pH value of the different foods was determined by means of a Beckman pH meter, using glass and calomel electrodes.

Relative Quality

The grade of eggs was determined by candling. Their relative quality was measured by comparing their odor, loss in weight, and increase in air cell size and by an examination of the egg albumin for appearance and texture.

The relative quality of fruits and vegetables was evaluated by organoleptic observations, ascorbic acid (vitamin C) content, and bacteria counts. The organoleptic tests included a comparison of odor, flavor, texture, surface discoloration and drying, and general appearance.

The bacteriological condition of the foods studied was determined by means of plate counts as described by Geer, Murray and Smith (1933).

The ascorbic acid content of the samples was determined whenever possible, because vitamin C is considered to be a good index of quality of fruits and vegetables. Their vitamin C content closely parallels their quality as regards variety, overmaturity, length of time in storage, and overcooking.

In this investigation the ascorbic acid content of the test foods was determined by the 2,6-dichlorophenolindophenol dye titration method of Tillmans, Hirsch and Hirsch (1932) as described by Maclinn and Fellers (1938). The dye solution was standardized according to the method of Buck and Ritchie (1938). The vitamin C content was calculated as milligrams of ascorbic acid per 100 grams on a moist basis or, in cases where dehydration occurred, it was calculated as milligrams per one gram of dry matter.

OPERATING CONDITIONS

The refrigerators were adjusted so that they maintained a cabinet temperature within 1°F. of each other. Different conditions with regard to door openings and food load were set up in order to determine their effect on the operation of the refrigerators.

The temperature and relative humidity of the refrigerators were determined when the cabinets were empty and again when they contained a normal food load, consisting of representative foods and jars of water. A tray of ice cubes was frozen each day and articles of food were replaced by others at room temperature in order to simulate conditions in a typical household. An average of twenty-five door openings per day was made in both of these tests, for it had been found that household refrigerators are opened about twenty-five times a day.

The daily power consumption during these tests was calculated from the kilowatt hour and running time readings obtained as described above.

Effect of Food Load on Temperature and Relative Humidity

There was no noticeable effect on the average temperature within the cabinets caused by different food loads. However, as was to be expected, when quantities of hot foods were placed in the cabinets a temporary rise in temperature was observed.

The effect of food load and door openings on the relative humidity of the cabinets is presented in Table 1. An average-sized food load caused an increase of 10–15 percent in the relative humidity.

TABLE 1. EFFECTS OF LOAD AND DOOR OPENINGS ON REFRIGERATOR HUMIDITIES AT 41°F.

Load and Door Openings	Relative Humidity, percent	
	Refrigerator No. 1	Refrigerator No. 2
Cabinet Unloaded		
Doors closed	41	55
Doors opened*	51	65
Cabinet Loaded		
Doors opened*	61	80

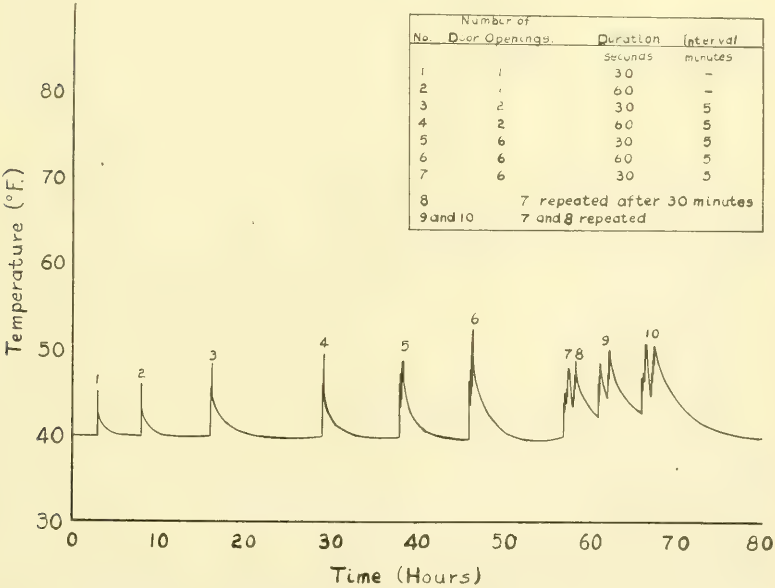
*Opened 25 times a day.

Effect of Door Openings on Temperature and Relative Humidity

As shown in Table 1 door openings caused a 10 percent increase in the relative humidities within the refrigerators.

Both refrigerators maintained a fairly constant temperature (within 1°F.) when left at rest. However, the door openings had a marked effect on the temperature of the cabinets, due to the denser cold air flowing out and being replaced by warmer air from the room. The rise in temperature was governed by the number of door openings made, their duration, and their frequency.

Figure 2, taken from typical temperature charts, illustrates the effect of door openings on the cabinet temperature. The normal operating temperature of a



No.	Number of Door Openings.	Duration	Interval
		Seconds	minutes
1	1	30	–
2	1	60	–
3	2	30	5
4	2	60	5
5	6	30	5
6	6	60	5
7	6	30	5
8	7 repeated after 30 minutes		
9 and 10	7 and 8 repeated		

Figure 2. Effect of Door Openings on Refrigerator Temperature.

domestic refrigerator is 40°F. Opening the door once for 30 seconds caused a rise in temperature of five degrees, while a six-degree rise was caused when the time was doubled. When the door was opened twice within five minutes, the temperature rose about eight and nine degrees when the doors were kept open 30 and 60 seconds, respectively.

Six door openings occurring within five minutes of one another and lasting for 30 and 60 seconds caused a rise in temperature of nine and thirteen degrees, respectively. When six door openings were made within five minutes of one another and for 30 seconds duration each, and this procedure repeated after one half hour, the maximum rise in temperature was eleven degrees. This test may be considered as approximating conditions in a home refrigerator during a meal hour.

The return of the refrigerators to normal temperature was quite rapid. A temperature within two degrees of normal was reached in from one-half to one hour after one or two door openings.

After a series of door openings the recovery time was longer, one and one-half hours being required to reach 42°F., after a series of six door openings; while after 12 openings within an hour and a half, the time required was three and one-half hours. When these door openings were made during the three meal hours of a day, the mean refrigerator temperature was approximately five degrees higher than the theoretical setting for about 12 hours, or 50 percent of the time.

The rise in cabinet temperature was influenced by the length of time the doors were left open and also by the number of openings, the latter having the greatest effect. For instance, two door openings for 30 seconds each caused a greater increase in temperature than one opening for 60 seconds.

Although the door openings did cause fluctuations in the refrigerator temperatures, the increases in temperature did not noticeably affect the keeping quality of the foods stored therein.

Effect of Load, Door Openings, and Operating Temperatures on Power Consumption

No great difference was noted in the power consumption of the refrigerators when different sized loads were present. Table 2 shows the effect of door openings and operating temperature on power consumption. The door openings caused an increase in power consumption of 9 to 11 percent.

A decrease in the operating temperature of only six degrees, to 35°F., required 80 percent more energy than that required at 41°F.

Table 2. Effect of Door Openings and Operating Temperatures on the Power Consumption of Loaded Domestic Refrigerators

Refrigerator	Temperature °F.	Door openings per day	Kilowatt hours consumed per day
1	41°	none	0.550
1	41°	25	0.600
1	35°	25	1.082
2	41°	none	0.606
2	41°	25	0.675

Discussion

Home electric refrigerators should be operated at the temperature recommended by the manufacturer, which is usually 40°F. Operation at lower temperatures increases the power consumption tremendously while higher temperatures are not so efficient for the storage of food.

The relative humidity within the refrigerators was increased by door openings because of the entrance of air from the room which, being at a much higher temperature, contained relatively large quantities of moisture.

Refrigerator door openings removed a part of the cooled air from the cabinet so that two door openings caused a higher temperature rise than one, although the total time the door remained open was the same in both cases.

In order to keep the temperature fluctuations caused by door openings at a minimum, it is to be recommended that during the preparation of meals the housewife remove as many articles as possible at one time rather than make several individual trips to the refrigerator. Care should also be taken to keep the door open for as short a time as possible.

STORAGE OF FRESH EGGS

Strictly fresh eggs* were selected for uniform shape and size and stored in one dozen lots in various types of containers and at different humidities at approximately 41°F. The purpose of this study was to determine how long eggs may be safely stored in a domestic refrigerator and the optimum storage conditions.

To determine the amount of deterioration, samples were candled each week and the loss of weight determined by direct weighing. The air cell was outlined in pencil and the relative increase determined by measuring the increase in size of the periphery. Samples were also broken and examined for changes in the albumin.

Deterioration in Quality

At 41°F. and at relative humidities of 40 to 100 percent, no evidence of mold growth was found in the eggs and all samples still candled to Grade A specifications, even at the end of four weeks' storage.

No changes in the appearance of the albumin could be attributed to the various methods of storage.

The loss of weight and the increase in the size of the air cell were not excessive under any of the storage conditions.

Effect of Humidity on the Quality of Eggs

The average loss of weight of the various samples is given in table 3. The eggs in covered dishes (100 percent relative humidity) actually showed a gain in weight, amounting to almost 0.5 percent in four weeks.

There was a gradual loss in weight of the eggs loosely stored in wire baskets, which was inversely proportional to the humidity; the eggs stored at 40 percent relative humidity lost 2.0 percent of their weight in a month; while those stored at 58 percent humidity lost only about one percent.

---

*Acknowledgment—The eggs were supplied, selected and graded through the courtesy of Mr. John H. Vondell, Poultry Department, Massachusetts State College.

Storage in 100 percent relative humidity caused a relatively small increase in the size of the air cell. The rate of increase in air cell size of the wire basket samples was approximately the same in every case for three weeks, but at the end of four weeks the samples stored at 40 percent humidity had a 20 percent larger air cell than the eggs stored at 58 percent relative humidity.

The air cells of the covered samples increased as rapidly as the others during the first week and then became fairly constant.

The loss of weight and increase in size of the air cell were therefore proportional to the length of storage and inversely proportional to the humidity.

TABLE 3. LOSS OF WEIGHT OF EGGS DURING STORAGE AT 41°F.

Container	Relative Humidity percent	Average Loss of Weight percent				Increase in Periphery of Air Cell, mm.			
		Weeks Stored				Weeks Stored			
		1	2	3	4	1	2	3	4
Wire baskets.	40	0.3	0.6	1.1	2.0	4.5	6.2	7.8	11.2
Wire baskets.	58	0.0	0.2	0.2	0.9	3.7	5.9	7.5	8.4
Cartons . . .	40	0.6	0.9	1.9	1.9	2.5	3.0	6.6	7.8
Cartons.	58	0.5	0.6	1.0	1.3	2.7	5.3	7.1	7.8
Covered dishes. . .	100	0.0	+0.2	+0.4	+0.4	2.5	3.6	2.8	3.1

Effect of Containers on the Quality of Eggs

Three methods of storage were used in these tests: (1) the eggs were stored loosely in wire baskets placed in the refrigerator, (2) in glass-covered dishes, and (3) in conventional cardboard egg boxes.

The increase in air cell size and weight losses in these tests were not significant so far as the quality of the eggs was concerned.

Discussion

If fresh eggs can be purchased more economically in quantity, it is evident that they may be safely stored in the ordinary domestic refrigerator for at least a month without serious deterioration.

The eggs used in this work were produced under particularly sanitary conditions. This may account for the fact that no mold growth was observed during storage at 100 percent relative humidity.

The shells of the eggs stored in the covered dishes were observed to be damp and it is assumed the increase in weight was due to absorption of moisture by the egg or possibly condensation on its surface.

STORAGE OF LEFT-OVER FOODS

Various vegetables such as creamed mashed potatoes, frozen peas, frozen broccoli, and canned snap beans were prepared for serving by ordinary home methods. Samples were stored with portions of the cooking juices, if any, in corresponding positions in the two refrigerators. Fresh tomatoes and radishes were sliced as for use in a salad and stored as left-overs.

The refrigerators were set at their normal operating positions and their mean temperatures varied between 39°F. and 42°F. throughout the tests. The temperatures of the refrigerators themselves varied one from the other by only about 1°F.

Ordinary refrigerator dishes with loose fitting glass covers and small custard dishes with oiled silk covers were used as containers. The humidity in both types of covered dishes was 100 percent. The dishes were used both covered and uncovered so that a wide range of storage humidities (from 42 to 100 percent) was obtained. Thus it was possible to determine the effect of humidity on the keeping quality of the foods.

Ordinary household conditions of load and door openings were approximated in most cases but these conditions were varied in order to obtain different relative humidities in the boxes.

Several samples were prepared for each test condition so that a complete sample was available each day for analysis.

The tests were run for at least four days and samples removed periodically to determine the change in quality. The tests for quality consisted of determinations of the loss in weight, vitamin C content, moisture content, change in pH value, and organoleptic tests.

Approximately 25-gram samples were used for the ascorbic acid determinations. At first representative samples were taken directly from the stored foods but later it was found advisable to grind the whole storage sample and then sample the ground-up material for the ascorbic acid determination.

On account of the possibility of dehydration during storage especially at the lower humidities, the ascorbic acid content is reported on a dry weight basis.

Change in pH Value During Storage

In no instance did the pH value of any of the foods show a significant change. The maximum change in four days storage was only 0.4 pH units. No variation in pH value could be attributed to the differences in humidity.

From these results it was evident that the pH value could not be used as an indicator of spoilage or autolytic changes in foods stored in a refrigerator under these conditions.

Effect of Humidity on the Loss of Weight During Storage

The percentage loss of weight of the various foods at the different storage humidities for several tests is summarized in table 4. For any one vegetable the same size sample was used and stored in similar containers. As the humidity was reduced from 100 percent there was a progressive loss of weight, due to the evaporation of water. This loss amounted to as much as 15 to 28 percent in four days at the lower humidities, even in the case of mashed potatoes and fresh vegetables stored without juice such as radishes and sliced tomatoes.

At humidities above 75 percent the loss of weight was 10 percent or less. At 100 percent relative humidity the loss in weight was only about 1 percent. It should be noted that the loss of moisture appears to be a direct linear function of the time and depends on the relative humidity.

It was found that up to 5 percent loss in weight could occur without noticeable deterioration in appearance.

TABLE 4. LOSS OF WEIGHT IN LEFT-OVER VEGETABLES DURING STORAGE AT 41°F.

Relative Humidity Percent	Loss of Weight, percent Days Stored				Loss of Weight, percent Days Stored			
	1	2	4	5	1	2	4	5
	Creamed Mashed Potatoes				**Cooked Frozen Peas**			
100	0.8	1.0	1.2	2.1	0.6	1.0	1.2	0.9
65	3.9	5.3	13.4	—	4.1	5.0	10.2	—
55	3.2	7.1	13.7	17.4	3.6	7.9	15.2	18.8
51	8.4	9.8	22.3	—	4.3	6.2	11.5	—
42	3.7	10.1	15.2	19.6	4.0	7.8	16.2	21.2
	Cooked Frozen Broccoli				**Reheated Canned Snap Beans**			
100	0.5	1.1	1.3	1.3	0.5	0.7	1.0	1.5
84	5.6	7.8	10.7	—	2.0	3.9	5.1	—
75	2.7	4.8	9.8	—	2.8	4.5	7.6	—
62	5.7	9.8	16.1	—		—	—	
59	7.1	12.0	23.9	—	4.2	9.0	11.6	—
55	3.2	7.8	16.0	22.8	4.3	6.0	11.8	14.4
42	6.5	10.0	20.8	26.8	3.5	8.0	15.6	20.5
	Sliced Tomatoes				**Scored Radishes**			
100	0.1	0.1	0.6	—	0.0	+0.3	+0.2	—
84	2.2	5.0	13.1		—	—	—	—
80	2.8	4.8	8.9	—	—	—	—	—
65	5.5	9.6	18.6		—	—	—	—
62	6.6	10.8	14.6	—	—	—	—	—
55	3.4	9.2	17.1	—	6.7	7.6	23.7	—
42	5.4	6.7	17.4	—	6.3	14.8	28.3	—

Deterioration of Organoleptic Qualities

The keeping quality of the vegetables at 41°F., as far as appearances, taste, and aroma are concerned, was found to depend on the humidity of the storage atmosphere. In other words, the loss of tenderness, characteristic odor, and flavor as well as discoloration paralleled the extent of dehydration.

Dehydration occurred only in the surface layers of the foods, the lower layers being of as good quality in all respects as the covered samples.

For simplification and purposes of comparison the quality of the different foods stored under the various conditions of humidity has been evaluated in table 5. Typical organoleptic observations made on peas are recorded in table 6.

The storage of left-overs in covered containers, that is in an atmosphere saturated with water vapor, resulted in least deterioration. All the vegetables tested, except sliced tomatoes, kept very well for at least four days at 100 percent relative humidity, whether stored in glass-covered or oiled-silk covered dishes. At the end of four days the quality was practically as good as it was at the start of the test. Surface drying and discoloration were practically eliminated under these conditions.

TABLE 5. EFFECT OF HUMIDITY ON QUALITY OF LEFT-OVERS STORED AT 41°F.

Relative Humidity percent	Score* Days Stored					
	0	1	2	3	4	5
			Creamed Mashed Potatoes			
100	100	100	100	—	80	80
65	100	90	80	—	40	—
55	100	80	70	—	—	20
51	100	80	80	—	20	—
42	100	80	70	—	-	20
			Cooked Frozen Peas			
100	100	—	100	—	100	100
65	100	70	50	—	0	—
55	100	—	50	—	—	0
51	100	70	40	—	0	—
42	100	—	50	—	—	0
			Cooked Frozen Broccoli			
100	100	100	100	—	90	80
84	100	100	90	—	80	—
75	100	90	90	—	70	—
62	100	90	80	—	60	—
59	100	90	80	—	60	—
55	100	80	70	—	—	0
42	100	80	70	—	—	0
			Reheated Canned Snap Beans			
100	100	100	100	—	100	100
84	100	100	90	—	70	—
75	100	90	60	—	20	—
59	100	80	60	—	20	—
55	100	80	60	—	—	30
42	100	80	60	—	—	20
			Sliced Tomatoes			
100	100	100	100	0	0	—
84	100	100	80	—	—	0
80	100	80	80	70	20	—
65	100	70	40	30	0	—
62	100	80	40	—	—	0
55	100	80	60	—	0	—
42	100	80	70	—	0	—
			Radishes			
100	100	100	100	—	90	—
55	100	80	70	—	0	—
42	100	80	70	—	0	—

*The food samples were graded and scored as follows:

Defect	Severe	Slight
Dehydration	−20	−10
Discoloration	−20	−10
Loss of tenderness	−20	−10
Loss of flavor	−20	−10
Loss of odor	−20	−10

Original fresh sample — Score 100
Spoiled sample — —Score 0

TABLE 6. ORGANOLEPTIC OBSERVATIONS ON LEFT-OVER PEAS STORED AT 41°F.

Relative Humidity percent	Days Stored 1	2	4
		Aroma	
100	Characteristic	Characteristic	Characteristic
65	Faint pea odor	Faint pea odor	Dry hay odor
51	Faint pea odor	Faint pea odor	Dry hay odor
		Color	
100	Characteristic	Characteristic	Characteristic
65	Slightly faded	Slightly faded	Black
51	Slightly faded	Slightly faded	Black
		Dehydration	
100	None	None	None
65	Surface dried	Slightly shrivelled	Badly shrivelled
51	Surface dried	Slightly shrivelled	Badly shrivelled
		Tenderness	
100	Tender	Tender	Tender
65	Tender	Less tender	Very tough
51	Tender	Less tender	Very tough
		Flavor	
100	Characteristic	Characteristic	Characteristic
65	Characteristic	Slightly off	Dry pea flavor
51	Characteristic	Off flavor	Dry pea flavor

Sliced tomatoes kept well in covered dishes for two days but spoiled in four days.

The storage of left-overs in uncovered containers resulted in a loss of aroma, surface drying, discoloration, and a loss in tenderness and flavor of the exposed surfaces at the end of four days. These changes were observed even at humidities as high as 84 percent.

At humidities between 42 and 60 percent, no significant organoleptic differences in the samples could be detected. However, on and after the second day, food stored at 65 percent relative humidity showed less discoloration, surface drying, etc., than did samples at 51 percent and lower humidities. When the humidities were raised to 84 and 62 percent this difference in quality was evident after the first day of storage. Uncovered foods, although inferior to the corresponding covered samples, were of fair quality when stored for one day at relative humidities up to 75 percent, or for two days at humidities of from 75 to 84 percent.

Vitamin C Content

The vitamin C (ascorbic acid) content of the various refrigerated foods is presented in table 7. Because of the wide variations in the rate of loss of vitamin C from different lots of the same vegetable, several determinations were made of the loss in one vegetable (broccoli) stored at various humidities.

From these data it appears that the rate of loss of vitamin C is much greater during the first day of storage than during the rest of the period. In broccoli for instance, at 100 percent relative humidity, 57 percent of all the vitamin C lost in four days was lost during the first day.

In only one day 20 to 60 percent of the vitamin C content of the foods tested was lost, while in four days the total losses ran as high as 90 percent.

TABLE 7. VITAMIN C CONTENT OF LEFT-OVERS STORED AT 41°F.

Relative Humidity percent	Ascorbic Acid, milligrams per gram*				
	Days Stored				
	0	1	2	4	5
	Creamed Mashed Potatoes				
100	0.20	0.13	0.07		0.04
55	0.20	0.14	0.09		0.04
42	0.20	0.12	0.06		0.04
100	0.22	0.18	0.14	0.03	
65	0.22	0.18	0.13	0.03	
51	0.22	0.15	0.10	0.02	
	Cooked Frozen Peas				
100	0.36	0.24	0.17		0.13
55	0.36	0.21	0.15		0.16
42	0.36	0.22	0.16		0.11
100	0.29	0.15	0.09	0.08	
65	0.29	0.14	0.09	0.06	
51	0.29	0.13	0.08	0.05	
	Reheated Canned Snap Beans				
100	0.29	0.12	0.11		0.09
55	0.29	0.12	0.08		0.08
42	0.29	0.17	0.12		0.09
100	0.28	0.19	0.16	0.21	
75	0.28	0.21	0.18	0.22	
59	0.28	0.22	0.18	0.20	
	Scored Radishes				
100	1.80	1.10	0.94	1.62	
55	1.80	0.72	0.62	1.39	
42	1.80	0.77	0.73	1.53	

Relative Humidity percent	Ascorbic Acid, milligrams per gram*			
	Days Stored			
	0	1	2	4
	Sliced Tomatoes			
100	0.80	0.67	0.65	
55	0.80	0.65	0.61	
42	0.80	0.54	0.47	
100	0.63	1.02	1.20	
84	0.63	0.95	0.98	
62	0.63	0.89	1.05	
100	2.01	1.72	1.55	
84	2.01	1.41	1.35	
62	2.01	1.75	1.58	
	Cooked Frozen Broccoli			
100	1.94	0.99	0.77	0.30
55	1.94	0.99	0.76	0.66
42	1.94	0.81	0.72	0.50
100	3.48	2.36	1.60	1.86
75	3.48	2.65	1.77	2.38
59	3.48	2.91	2.36	1.90
100	2.77	2.19	2.19	1.47
84	2.77	2.59	2.56	1.27
62	2.77	1.81	1.99	1.33
100	5.38	4.86	4.23	2.62
75	5.38	4.10	3.50	2.79
55	5.38	3.86	3.31	2.75
100	5.81	3.71	3.42	3.56
78	5.81	4.75	4.46	3.54
57	5.81	4.88	4.07	3.17

*Milligrams of ascorbic acid per gram of vegetable on a dry weight basis.

Increase in Vitamin C Content

Apparent increases in the vitamin C content during storage were found at times in snap beans, radishes, tomatoes, and broccoli, no matter which method of sampling was used. From table 8 it may be seen that most of the increases occurred toward the end of the test.

TABLE 8. NUMBER OF TIMES APPARENT INCREASES IN VITAMIN C OCCURRED.

Left-over	Number of Tests Run	Number of tests Showing Apparent Increase in Vitamin C	Time when Increase Occurred
Creamed mashed potatoes	8	0	
Cooked frozen peas	8	0	
Broccoli	20	6	4 at 4th day 2 at 6th day
Snap beans	8	4	4 at 4th day
Tomatoes	12	4	4 at 1st day*
Radishes	4	4	4 at 4th day

*Increase continued to end of test on 4th day.

Total bacteria counts were made in conjunction with the ascorbic acid determinations to see if these increases could possibly be due to the growth of microorganisms, but no correlation was found to exist in the tests that were made.

Vitamin C Content of Juices of Left-overs

Any decrease in the vitamin C content of creamed mashed potatoes, sliced tomatoes, and radishes was presumably due to oxidation. In the case of the vegetables such as broccoli, which were stored with their juices, the question arises as to whether or not some of the ascorbic acid was dissolved out of the vegetable by the juices during storage. Tests were conducted to determine whether or not this assumption was correct.

In table 9 it may be seen that the vitamin C content of the vegetable itself gradually fell as usual. The vitamin C content of the juice, however, usually increased during the first day or two and then decreased. Thus, it is evident that some of the loss of the vitamin C of the vegetable was due to its removal by the surrounding juices.

TABLE 9. VITAMIN C CONTENT OF LEFT-OVER BROCCOLI AND ITS JUICE, STORED AT 41° - 42°F.

Relative Humidity percent	Ascorbic Acid, milligrams per gram of Broccoli				Ascorbic Acid, milligrams per milliliter of Juice			
	Days Stored				Days Stored			
	0	1	2	4	0	1	2	4
100	5.81	3.78	3.71	4.16	0.47	0.46	0.47	0.49
78	5.81	4.75	4.46	3.54	0.47	0.49	0.49	0.42
57	5.81	4.88	4.07	3.17	0.47	0.53	0.45	0.43
100	5.38	4.60	4.30	2.79	0.49	0.58	0.45	0.35
75	5.38	4.10	3.50	3.69	0.49	0.55	0.49	0.38
55	5.38	3.86	3.31	2.75	0.49	0.55	0.48	0.37

*Ascorbic acid calculated on a moisture-free basis.

Spoilage of Left-over Foods

In 76 samples of food stored for five days at approximately 41°F., only seven cases of spoilage were detected organoleptically. Six of these spoiled samples were sliced tomatoes, the other was snap beans which spoiled in a covered dish in five days. The only uncovered sample which spoiled was sliced tomatoes, where detectable signs of spoilage were noted after four days.

Bacteria counts were made on some stored left-over foods. None of the samples tested showed visible signs of spoilage. In storage periods up to five days, only slight increases in the number of microorganisms were observed. However, in many cases there was a decided increase in the number of bacteria present in the samples after storage for seven days.

Discussion

The need of covering refrigerated foods is appreciated when it is considered that in only two days one-tenth of the weight of the food has evaporated into the air.

Considerable attention has been paid to the dehydration of foods in commercial cold storage, because a loss in weight means a loss of money. On the other hand, in home refrigeration the drying-out of the surfaces of the food and loss in quality are of primary importance.

The vegetables stored with juice lost approximately the same amount of weight as those without. It, therefore, seems probable that most of the evaporation occurred on the surfaces of the vegetables. In cases where juice was present, the vegetables probably acted as a wick. This seems reasonable when the large surface of the exposed vegetables as compared to that of the liquid is considered.

It should be noted that even at humidities of 80 to 84 percent there was as much as 10 percent loss of weight in four days. It was, therefore, found advisable to cover all left-over foods to prevent loss of moisture and deterioration in quality.

Plausible reasons for the apparent increase in vitamin C content would appear to be formation of some substance which reduces the indophenol dye, sampling, or the possible production of ascorbic acid-like substances by microorganisms, or a breakdown of a complex ascorbic acid compound in the food. As stated previously, changing the method of sampling did not eliminate these increases.

Storage, of the foods tested, in domestic refrigerators in covered or uncovered dishes appeared to practically eliminate microbial spoilage for at least five days. High storage humidity did result in spoilage of sliced tomatoes but as they are seldom, if ever, stored in the home, this is of no practical significance except that it demonstrated the effect of high humidity on the growth of microorganisms. This was supported by the plate counts of two of the foods.

FLAVOR TRANSFER IN HOME REFRIGERATORS

Canned crab meat and salt codfish were used as contaminating substances; unsalted creamery butter and processed cream cheese were used as flavor absorbers.

The flavor emitters were stored on the middle shelf of the refrigerator while the absorbers were placed in corresponding positions on the bottom shelf. Uncovered and covered dishes of various types were used for storage of the butter and cheese. Samples were compared periodically for flavor, between themselves and with a control. A similar test was run using ordinary refrigerator jars with various types of covers.

In all these tests the doors of the refrigerators were opened a normal number of times each day and a medium-sized load kept in the boxes. Activated charcoal was removed from a filter present in the refrigerator so that it would not interfere with the test.

TABLE 10. FLAVOR TRANSFER IN A REFRIGERATOR AT 41°F. AND 65 PERCENT RELATIVE HUMIDITY.

Storage Conditions	Flavor			
	Storage Period			
	24 hours		48 hours	
	Butter	Cheese	Butter	Cheese
Uncovered dishes	Very bad	Very bad	Very bad+	Very bad+
Glass-covered dishes	Trace	None	Slight	Slight
Dishes with oiled-silk covers	Slight		Bad	
Original wrappings	Trace	None	Trace	Slight
Sealed jars	None	None	None	None

The data presented in table 10 show that cheese and butter picked up more flavors when uncovered than when stored in glass-covered refrigerator jars. Even the covered dishes did not completely prevent flavor transfer, however.

Butter wrapped in parchment and cream cheese rewrapped carefully in its original carton absorbed no more flavors than when stored in glass-covered refrigerator dishes. Dishes with oiled-silk covers permitted the transfer of flavor to butter to a greater extent than glass-covered jars but gave more protection than open containers.

Sealed jars were the only containers which offered complete protection against the absorption of flavor.

No absorption of acetic acid by water in dishes with glass or oiled silk covers could be detected by titrating with sodium hydroxide.

Discussion

The experimental results indicate that the obvious solution to the problem of odor transfer in a refrigerator is to eliminate the source of contamination through proper storage methods. The other foods then could be safely covered with whatever type of covers was available.

SUMMARY

A study has been made of (a) the operation of an electric refrigerator, (b) the storage of eggs in domestic refrigerators, (c) the storage of left-over food, and (d) the flavor transfer in domestic-type refrigerators.

1. The average operating temperature of a mechanical refrigerator was found to be several degrees above the theoretical setting, while the operating costs were greatly increased by lowering this temperature only a few degrees.
2. Eggs can be safely stored at least a month without serious loss in quality. The preferable method is to use covered containers.
3. Left-over foods were preserved best by storing in covered containers, in which they kept in good condition for at least four days.
4. A considerable amount of the vitamin C in left-over foods was lost during refrigeration, most of it during the first day of storage.
5. Storage at 40°F. prevented significant increases in the number of microorganisms in cooked left-overs for at least five days.
6. Flavor transfer in a home refrigerator was not entirely prevented by ordinary glass or oiled-silk covers; sealed jars were the only absolute protection.
7. Any type of dish cover reduces the amount of flavor transfer; however, oiled-silk covers are very inefficient in this respect.

CONCLUSIONS

With proper use, an efficient refrigerator reduces the development of food poisoning organisms to a minimum and effectively preserves the quality and vitamin content of foods.

Storage of fresh and left-over vegetables and fruits at high humidities, preferably in covered containers, best preserves their quality and nutritive value, while meats keep best when loosely wrapped.

One objectionable feature met with in home refrigeration is transference of taste from one food to another. However, by using the proper methods of storage, this contamination can be eliminated.

LITERATURE CITED

Association of Official Agricultural Chemists, 1940. Official and tentative methods of analysis. Fifth Ed. Washington, D. C. 757 pp.

Buck, R. E., and Ritchie, W. S., 1938. A new method for the standardization of the dye used for the determination of cevitamic acid. Ind. Eng. Chem. Anal. Ed. 10, 26.

Frigidaire Corporation, Dayton, Ohio, 1929. Food Preservation in our Daily Life. 84 pp.

Geer, L. P., Murray, W. T., and Smith, E., 1933. Bacterial content of frosted hamburg steak. Am. J. Pub. Health 23, 673.

Maclinn, W. A., and Fellers, C. R., 1938. Ascorbic acid (vitamin C) in tomatoes and tomato products. Mass. Agr. Expt. Sta. Bul. 354. 39 pp.

Moyer, J. A., and Fittz, R. U., 1932. Refrigeration. McGraw-Hill Book Co Inc., New York, N. Y. Second Ed. 538 pp.

Tillmans, J., Hirsch, P., and Hirsch, W., 1932. The reducing capacity of plant foodstuffs and its relation to vitamin C. Ztschr. Untersuch. Lebensm. 63, 1.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 409 October, 1943

The Grape Plume Moth

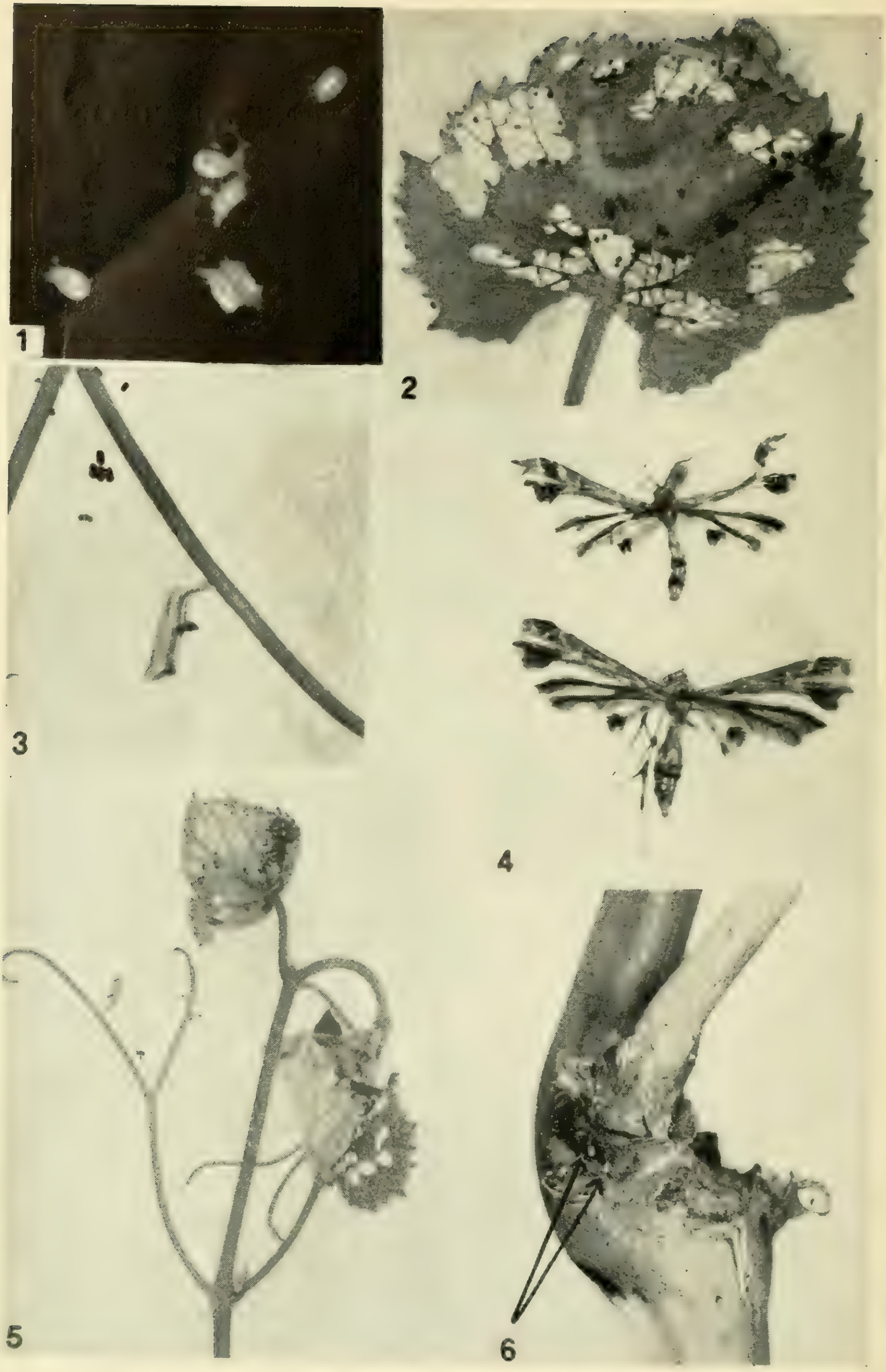
With Notes on Other Pests of Grapes in Massachusetts

By W. D. Whitcomb, Wm. E. Tomlinson, Jr., and E. F. Guba

Part I reports for the first time the complete life history and control by dormant spraying of the Grape Plume Moth, an obnoxious pest in home vineyards in eastern Massachusetts.

Part II describes briefly other insects and diseases likely to attack grapes and includes a complete spraying and dusting schedule for their control.

MASSACHUSETT STATE COLLEGE
AMHERST, MASS.



1 - 4. Stages of the Grape Plume Moth.
    1. Eggs enlarged about 10 times.
    2. Full-grown larva on leaf which has been broken from a webbed shelter. 1½×
    3. Pupa attached to tendril. 2×
    4. Adult or moth: upper, male; lower, female. 2½×
5. Typical Webbed Shelters of Caterpillar at End of Feeding Period.
6. Eggs in Typical Location at Base of Cane.

PART I.—THE GRAPE PLUME MOTH[1]

By W. D. Whitcomb, Research Professor, and Wm. E. Tomlinson, Jr.,
Laboratory Assistant, Department of Entomology[2]

Although several species of wild grapes are native to Massachusetts and many kinds of cultivated grapes thrive in this climate with a minimum of care and damage from injurious insects, there are very few commercial vineyards in the State. However, thousands of "backyard" gardens have one or more grapevines which are grown for shade or ornamental value as well as for fruit and juice. On arbors and trellises in "backyard" gardens, the vines are seldom pruned as heavily or systematically as is recommended by horticultural authorities. The thick and tangled growth of these vines provides ideal conditions for the grape plume moth which has become abundant in eastern Massachusetts.

HISTORY AND DISTRIBUTION

The grape plume moth is generally distributed over the northeastern United States and southeastern Canada, including the Great Lakes region. It appears to be more abundant within 50 miles of the coast, but this statement is neither verified nor explained. In eastern Massachusetts, especially in Metropolitan Boston, nearly all vines have been attacked in recent years and the characteristic webbed leaves have been abundant and conspicuous. Typical infestations in the vicinity of Waltham, Massachusetts, in 1939 (15) showed from 32 to 78 percent of the cane tips to be infested. In spite of these relatively heavy infestations, the grape plume moth has not become a serious pest in commercial vineyards in Massachusetts and consequently had not been studied carefully. It has been the subject of brief reports for about 50 years, but apparently the complete life history had not been worked out previous to the studies herein reported (15).

Lintner (5) in 1896 summarized the observations of Fernald, Saunders and Riley to conclude that there is one generation annually, and that the insect hibernates either as the egg on grape canes or as a moth similar to other *Pterophoridae*, especially in England.

Quaintance (10) in 1921 stated "The life history of this insect is imperfectly known"; and Pettit (9) in 1933, reporting it in the vicinity of Kalamazoo, Michigan, said "This dainty little moth produces two generations each year . . . The larvae of the first generation do all the damage, for by the time the second generation appears the grapes and leaves have become well-formed and hardened." Slingerland and Crosby (12) in 1922 say, "The eggs have not been observed . . . and it is not known whether there is a second brood or not, and whether the insect hibernates in the egg or adult stage."

The first complete life history records were published by the writers in 1940 (15).

---

[1] *Pterophorus periscelidactylus* Fitch.

[2] The writers gratefully acknowledge the assistance of William Garland, Technical Assistant, Department of Entomology, with the field work reported herein.

TABLE 1.—COMPARATIVE INFESTATION OF GRAPE VARIETIES BY THE GRAPE PLUME MOTH.

Waltham and Newton, Massachusetts, 1939-42.

Variety	Percent Tips Infested
Moore's Early	96.25
Delaware	75.23
Concord	72.28
Hartford*	57.64

*An old variety planted about 1880 and known locally as Hartford.

HOST PLANTS

The grape plume moth has been found only on the wild and cultivated varieties of the northern fox grape, *Vitis labrusca*. Only slight infestations have been observed on wild grapes, but most of the common varieties of cultivated grapes have been moderately or heavily infested.

Counts in the years 1939 to 1942 have shown more than 50 percent of the tips on "backyard" grape vines to be regularly infested.

DESCRIPTION

The grape plume moth, also called the gartered plume moth, is native to North America and was originally described by Asa Fitch in 1854 (3) as *Pterophorus periscelidactylus.* Sometime between 1888 (8) and 1896 (13) it was reclassified as *Oxyptilus periscelidactylus* (Fitch) where it remained until 1940 (7) when it was returned to *Pterophorus periscelidactylus* Fitch. The moth is typical of the family *Pterophoridae,* the wings being divided into feather-like sections which suggest the name plume moth. Metamorphosis is complete and there are four stages of development: egg, larva, pupa, and adult.

Egg

The average egg is .56 mm. long and .39 mm. wide, broadly elliptical in general shape but slightly narrower at one end. It is well rounded at the sides and ends, but in the center of the upper and lower surfaces there is a small flattened area. When first laid, the egg is glistening light yellowish green in color but it soon changes to a light iridescent brown.

Larva

When hatched, the larva is shiny and pale yellowish green in color. After the first molt, it is abundantly covered with relatively long pale hairs and has a fuzzy appearance throughout the remainder of its life. When full grown it is 13 to 16 mm. (about ½ inch) long. The head and thoracic shield are very nearly the same shade of yellowish green as the body.

Pupa

The pupa is 8 to 10 mm. long, naked, and light green or brown in color. It is distinguished by two parallel appendages protruding dorsally from the first abdominal segment. These "fins" are shaped somewhat like a spear point and are dark brown. Smith (13) refers to them as the "breast bone" although they are located on the back.

Adult

The moth is light brown with numerous dark brown spots on the abdomen, at the joints of the legs, and near the tips of the forewings. The forewings are divided into two parts with the cleft extending from the outer margin about 1/3 the length of the wings. The two upper plumes of the hindwings are chocolate brown with a lighter fringe and the lower plume is light brown with a dark brown tuft near the tip. The hindwings are divided into three parts, with the cleft between the upper and middle sections extending inward about one half the length of the wing and the cleft between the middle and lower sections reaching almost to the base. The wing spread is 15 to 18 mm. The legs are conspicuously long and slender, with two pairs of long tibial spurs on the hind legs and one pair on the middle legs.

LIFE HISTORY AND HABITS

The moth is not a strong flier and is most active at night. When at rest, the forewings are folded, enclosing the hindwings in a roll which is held at right angles to the body. In this position it often hangs by the front and middle legs with the body and hind legs perpendicular to the surface. In the insectary cages the average life of the moths was 7.87 days for the males and 11.55 days for the females, and observations in the field indicated that they were relatively short lived.

Oviposition

The eggs are laid singly but are frequently deposited in groups of two to ten. They are usually placed in the crevices around the axil of branches on one- or two-year-old canes (Fig. 6). In this location they are embedded in the pubescence on the cane and may not be visible to the naked eye although a small part of the egg is usually exposed. No eggs have been found directly on the current season's growth although they may be at the base of a new cane.

In the insectary one female moth laid 21 eggs in 4 days but the average number of eggs per female was 12.67. On caged potted vines, Concord and Delaware were equally attractive for oviposition but very few eggs were laid on Niagara.

An examination of 102 infested nodes from a normally infested vine showed an average of 3.19 eggs per node or bud; but since no eggs are laid on the current season's growth, only about 8 percent of the nodes on all of the canes were infested.

Incubation

Incubation begins soon after the eggs are laid and the developing larva is visible through the eggshell in 10 to 14 days. However, the larva remains in the eggshell throughout the winter and the average time spent as an egg is 320 days or slightly more than 10 months.

Growth of Larva

When first hatched, the small larvae crawl into the swelling bud and feed slightly on the unfolding leaves. As the shoot grows, the caterpillar fastens one or more terminal leaves together with silk and lives within the shelter thus formed. The average life of the larva is about 5 weeks, varying slightly with the season.

TABLE 2.—LENGTH OF LIFE OF THE LARVA OF THE GRAPE PLUME MOTH.
Waltham, Mass.

Year	Number of Days		
	Maximum	Minimum	Average
1939	38	30	32.0
1940	43	34	39.2
Average for the two years			35.6

Pupation

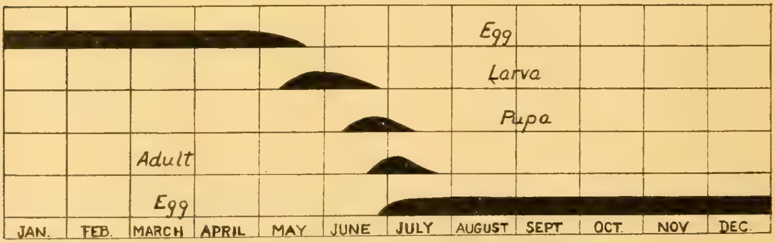
When ready to pupate, the mature larva suspends itself posteriorly from the leaf, usually within the web of its nest. Frequently it hangs downward from a leaf or tendril but it may be suspended at any angle from the surface. The pupation period lasts about 12 days but this may be extended by cool weather as in 1940 when an average of 17.13 days was required and one insect remained in the pupa stage for 27 days. The pupation records are shown in Table 3.

TABLE 3.—LENGTH OF PUPATION PERIOD OF THE GRAPE PLUME MOTH.
Waltham, Mass.

Year	Number of Days			
	Maximum	Minimum	Optimum	Average
1938	13	9	12	11.67
1939	13	10	12	11.90
1940	27	12	15	17.13
Average for the three years				12.64

SEASONAL HISTORY

Contrary to several published reports (9) (12), the grape plume moth has one generation annually in Massachusetts. The insect lives from mid-July to mid-May, including the entire winter, as a completely developed but unhatched larva.



SEASONAL HISTORY OF THE GRAPE PLUME MOTH.

About the time that the grape buds begin to swell and break open, usually May 10–15, the larva leaves the eggshell and enters an opening bud to feed. Feeding by the larva and the construction of its nest are most conspicuous during the last week in May and the first week in June. The caterpillar becomes full grown and begins to pupate about June 15 and the first moths appear about June 20, just before the grape blossoms open. Moth activity reaches its peak about July 1, and in the insectary practically all eggs have been laid and the moths have died by July 10. Incubation of the egg begins soon after it is deposited, and the young larva is developed in the egg by late July.

NATURE OF INJURY

Injury to grapevines by the grape plume moth is caused entirely by the larva or caterpillar. When first hatched, the larva enters the swelling bud and feeds slightly on the developing leaves. Occasionally this feeding injures or destroys an embryo flower bud.

As the larva grows, it fastens together the terminal leaves of the shoot with a web and feeds on the leaves in the shelter thus formed. In a few cases a blossom cluster enclosed in the nest is injured but usually the feeding is confined to the skeletonizing of the upper surface of the webbed leaves with an occasional hole being eaten in them.

As the cane grows, many of the webbed terminal leaves are torn and deformed as they break away from the web. Since the feeding by the larva is usually finished about the middle of June, the injury is only slightly noticeable by July and can scarcely be recognized by fall when the grapes are ripening.

The grape plume moth causes little actual loss of fruit and its injury is most annoying to home gardeners who take pride in the appearance of their grapevines.

CONTROL

Historical

In 1896 J. B. Smith in New Jersey (13) stated: "Practically there is no method of checking their increase, except by picking off the infested tips or crushing the caterpillars within the webbed leaves." Surface in 1911 (14), Britton in 1914 (2), Quaintance in 1921 (10), and Slingerland and Crosby in 1922 (12), all recommended hand-picking of the caterpillars as the only method for keeping the insect in check, especially on home plantings.

Surface (14) suggests "spray with any arsenite while pests are young"; and in 1933 Pettit (9) wrote: " . . . it is usually kept in check by the sprays used to control the grapeberry moth . . . It is best controlled by a spray of arsenate of lead applied just before blossoming time . . . " These are the only references to control with insecticides until 1940, when the writers (15) reported on the use of dormant sprays.

In recent years in eastern Massachusetts, great interest in the control of this insect has developed. Possibly this is due to heavier infestations or to greater interest in grapevines as ornamental plants about the home.

Natural Enemies

Insect parasites were not an important factor in keeping the grape plume moth under control in the vicinity of Waltham during the years when observations were made. Throughout the studies only 15 parasites were reared and in 1941 special collections of abnormal larvae which were suspected of being parasitized, yielded only 8 parasites. The following parasites[1] have been reared, all of them from larvae:

Family	Genus - Species
Braconidae	*Apanteles* sp. (undescribed)
Braconidae	*Microbracon* sp.
Ichneumonidae	*Campoplex* sp.
Eulophidae	*Horismenus microgaster* Ashm.
Pteromalidae	*Hypopteromalus inimicus* Mues.

Of these species, the Chalcid, *Hypopteromalus inimicus* Mues., has been recorded several times in Massachusetts as a secondary parasite on *Apanteles melanoscelus* (Ratzeburg) (6), a parasite of the gypsy moth. However, the five specimens reared from the grape plume moth at Waltham were definitely primary parasites.

Although insectivorous birds undoubtedly eat the larvae and pupae of the grape plume moth, no definite observations of their feeding on this insect are available.

Hand-Picking

Crushing the caterpillars in their nests on the tips of the shoots or breaking off and destroying the nests while the caterpillars are in them is the most common practice followed in combating this insect. However, personal experience has shown that hand-picking as practiced by the average home gardener does not prevent the development of normal infestations each year, and it is quite unsatisfactory to the gardeners who take pride in the appearance of their vines. On thick, unsystematically pruned vines it is difficult to find all of the nests and frequently some of the caterpillars leave their shelter and crawl to protected places before the nest is picked off. Although the moths are not strong fliers, there is a definite migration from vine to vine which may reinfest vines in the immediate vicinity each year.

Pruning

It is the opinion of the writer that regular, heavy, systematic pruning as recommended by specialists in grape culture has been one of the most important factors in preventing the establishment of the grape plume moth in commercial vineyards.

The eggs are laid at the nodes on one- or two-year-old canes (see p. 5) and most of these nodes are removed by careful pruning according to the Kniffin system or the high renewal system, the two most commonly followed in the Northeast (11), or by the spur or stool system, which is recommended for varieties of Vinifera (4). Furthermore, the heaviest infestations have been observed on unpruned vines or on vines which are unsystematically "cut back" and produce a thick bushy growth.

A small experiment on vines having an infestation of 7.6 and 7.7 eggs per 100 nodes showed that although the eggs are not uniformly located along the canes, the percentage of eggs removed by pruning was nearly equal to the percentage of nodes which was cut off.

---

[1] Determined by C. F. W. Muesebeck and others of the staff of Bureau of Entomology and Plant Quarantine, Division of Insect Identification.

TABLE 4.—REMOVAL OF GRAPE PLUME MOTH EGGS BY PRUNING.

Treatment	Number of Nodes on Vine	Number of Eggs on Vine	Nodes Removed		Eggs Removed	
			Number	Percent	Number	Percent
Moderate pruning	991	75	786	79.31	54	72.00
Light pruning	744	58	378	50.80	32	55.17

It is apparent that the removal of only 72 percent of the eggs on a vine does not provide effective control of the insect nor does it prevent a light or moderate infestation the following season. However, it is conceivable that the destruction of 72 percent or more of the eggs each year for several years will reduce the infestation to a minimum and aid greatly in preventing the plume moth from becoming abundant.

Arsenical Sprays

In spite of references (p. 7) to the contrary, the writers have never seen satisfactory control of the grape plume moth in backyard vineyards by spraying with arsenicals. To be sure, most of the treatments observed were made according to recommendations for controlling other pests and were not applied at an effective time for combating the plume moth, but the control was always noticeably unsuccessful.

In 1940 several backyard grapevines were sprayed with lead arsenate and bordeaux mixture. The application was made on May 1 when the buds were beginning to swell and just before the larvae of the grape plume moth began to hatch. The spray was applied very thoroughly at 250 pounds pressure. The results were unsatisfactory as shown in Table 5.

TABLE 5.—CONTROL OF GRAPE PLUME MOTH BY SPRAYING WITH ARSENICALS.

Treatment	Tips Infested—Percent
None	48
Lead arsenate 4 pounds – 100 gallons	51
Lead arsenate 4 pounds – 100 gallons Bordeaux mixture 8 – 8 – 100 Fish oil 1 quart – 100 gallons	40

In this experiment, the newly hatched larvae entered the swelling buds without feeding on outer bud leaves where the spray was deposited. After they have entered the bud, they are protected by the webbed leaves of their nest and are not susceptible to arsenical sprays.

In commercial vineyards the first application for combating the grape berry moth, the rose chafer, and the common grape diseases is not made until the blossom buds have developed, at which time the larvae of the grape plume moth are well established in their webbed nests.

Dormant Sprays

Soon after it was discovered that the grape plume moth hibernated as an egg on the canes, the writers began experimenting with dormant spray mixtures as ovicides.

Laboratory Experiments

Preliminary laboratory experiments in 1939, in which about 20 eggs on cut canes collected in the field were sprayed in the laboratory, indicated that oil emulsion, sodium dinitro cresylate, and liquid lime-sulfur were promising; but that peanut oil emulsion, a commercial rotenone spray, and a commercial cyclohexylamine mixture were less satisfactory.

Other laboratory tests in 1940 showed that oil emulsions and the greater concentrations of sodium dinitro cresylate were very toxic to the eggs, but that liquid lime-sulfur was less effective. These experiments are summarized in Table 6.

TABLE 6.—EFFECT OF DORMANT SPRAYS ON EGGS OF THE GRAPE PLUME MOTH IN THE LABORATORY.

Waltham, Mass., 1940

Material[1]	Number of Eggs		Percent Eggs Failing to Hatch
	Total	Hatched	
None	27	17	37.03
Liquid lime-sulfur 11%	29	6	79.31
Oil emulsion (Spra-Cream)			
Actual oil 1%	31	1	96.77
2%	25	2	92.00
3%	25	0	100.00
4%	29	0	100.00
Oil emulsion (Kleenup)			
Actual oil 3%	23	0	100.00
Oil emulsion (Nitro Kleenup)			
Actual oil 3%	37	0	100.00
Sodium dinitro cresylate			
½%	31	16	48.38
¾%	21	11	47.61
1 %	31	0	100.00
1 ¼%	28	2	92.85

[1] See notes for Table 7

Field Experiments

Following the laboratory studies, experimental dormant sprays were applied to heavily infested backyard vines in 1939, 1940, 1941, and 1942. In 1939 and 1940 the sprays were applied from a wheelbarrow sprayer producing about 125 pounds pressure from a hand-operated force pump, and in 1941 and 1942 a motor driven pump delivering about 1¼ gallons per minute at 250 pounds was used. The spray was applied very thoroughly and an attempt was made to wet all parts of the vines but this was difficult on some vines which had been pruned by the "haircut" system and afforded many protective crevices. No significant differences in the results from the two types of spraying equipment occurred but in some experiments the low pressure hand pump producing a greater volume appeared slightly more effective. A power sprayer delivering 4 gallons or more per minute at a pressure of 250 pounds or more would be very effective equipment. The sprays were applied when the buds were starting to swell and about two weeks before the larvae hatched. The actual date of application varied from April 9 in 1942 to April 21 in 1939, depending on the early spring development.

The effectiveness of the treatment is expressed as the percentage of available tips or new shoots (Fig. 5) which were infested with a larval web or nest. Counts were made from May 19 to June 4 when the activity of the caterpillars was at its height. If possible, at least 100 tips on each vine or trellis were selected at random and examined.

TABLE 7.—DORMANT SPRAYS FOR THE CONTROL OF THE GRAPE PLUME MOTH IN HOME VINEYARDS.
Waltham, Mass., 1939-1942

Material	Experiments Number	Tips not Infested Number	Tips Infested		Percent Control[5]
			Number	Percent	
None	11	390	885	69.41	....
Liquid lime-sulfur 11%	3	224	241	51.82	25.48
Oil emulsion[1] 3% actual oil					
Alone	4	570	153	21.16	69.51
Plus Nicotine sulfate 0.125%	1	81	19	19.00	72.62
Plus DNOC[2] 15 oz. – 100 gal.	1	82	18	18.00	74.06
Plus DNOCHP[3] 15 oz.–100 gal.	1	86	14	14.00	79.83
Sodium Dinitro Cresylate[4]					
½%	3	942	234	19.89	71.34
¾%	1	100	9	8.25	88.11
1 %	5	382	13	3.29	95.26
1 ½%	1	93	7	7.00	89.91

[1] In 1939 Kleenup, Cal. Spray Chem. Co., was used; in 1940 and 1941 Spra-Cream, B. G. Pratt Co.
[2] Dinitro cresol powder supplied by Dow Chemical Co.
[3] Dinitro phenol powder supplied by Dow Chemical Co.
[4] Elgetol supplied by Standard Agr. Chem., Inc.
[5] Abbott's formula (1).

Discussion of Materials

The natural infestation on unsprayed vines in the vicinity of Waltham is well shown by the average of 69.41 percent for the four-year period. Although individual counts ranged from 31.7 to 96.3 percent of the tips infested, the average tip infestation for each year was: 1939—65.56, 1940—75.08, 1941—81.95, and 1942—55.46 percent.

Lime-Sulfur. — In spite of promising results in laboratory tests, liquid lime-sulfur diluted 1 part with 8 parts of water was not effective in field experiments. In only one experiment was the infestation reduced significantly from that on the untreated vines. This material was applied to a white painted arbor in one test with disastrous effect on the paint.

Oil Emulsion. — Oil emulsion reduced the infestation about 80 percent when diluted to contain 3 percent actual oil. There was no significant difference between the commercial emulsions, Kleenup and Spra-Cream, and any emulsion of this type should be satisfactory. In 1941 when it was applied with a low volume pump, the oil emulsion was slightly less effective. It was evident that the oil spread with difficulty into the crevices among the loose bark where the eggs are laid and that a heavy, thorough application is necessary to give complete wetting on old grape canes. Although the tests in which nicotine sulfate, dinitro cresol powder, and dinitro phenol powder were added to the oil emulsion were limited to one experiment and therefore the results are not conclusive, the increased control did not seem great enough to warrant the additional cost. The addition of the dinitro powders appeared to aid the wetting of the spray, and this apparently contributed to the slightly better control as much as the added toxicity.

Sodium dinitro cresylate. — Elgetol was the most effective material used and was the only material which gave 85 percent or more control in the field experiments. When diluted to 1 percent it was most satisfactory. A ½ percent dilution lacked sufficient toxicity and a 1½ percent dilution was not significantly superior. Elgetol wet the rough bark of the canes very easily and thoroughly. It discolors paint badly and should not be used near buildings or on arbors which are painted with light colors.

SUMMARY AND CONCLUSIONS

Although the grape plume moth has not become a serious pest in commercial vineyards, it is an abundant and annoying pest in home vineyards, which include the great majority of grapevines in eastern Massachusetts.

The common varieties of cultivated grapes in New England, such as Concord, Delaware, and Niagara, are favorite hosts of this insect.

This bulletin, and a preliminary report on the same studies, give the first published description of the eggs of the grape plume moth as well as of the other life stages in detail.

This insect has one generation annually in Massachusetts. The moths, which are weak fliers, lay eggs in the pubescence of the canes at the axils of one- or two-year-old shoots. Incubation takes place soon after oviposition, but the larva does not leave the eggshell until the following year. The larva feeds for about 5 weeks and the average pupation period was 12.64 days, making the average time from the hatching of the caterpillar to the emergence of the moth about 7 weeks.

The grape plume moth lives as an egg or as a small larva in the eggshell from late June until the following May, a period of about 320 days. Hatching occurs about May 10 to 15 when the grape buds are breaking open, and the larva feeds and grows until mid-June. Pupation occurs in late June and the moths emerge and lay eggs in early July.

Injury to the vine is caused entirely by the feeding of the larva or caterpillar in the opening bud and at the tip of the new shoots where they fasten a few leaves into a nest. Only a few blossom buds are damaged, and the loss of fruit is slight.

Five species of parasitic insects have been reared from the larva of the grape plume moth, but in Massachusetts these and other natural enemies have been unimportant. Careful annual pruning by one of the recommended pruning systems removes 70 percent or more of the eggs, and is an important factor in keeping this insect in check, especially in commercial vineyards. Unsystematic pruning which does not remove a large portion of the old canes favors the establishment of the grape plume moth.

Hand-picking of the larvae and nests, or crushing the caterpillars in the nests, is the most common treatment used on "backyard" vines. This kills many of of the insects but does not prevent infestations from developing each year.

Lead arsenate has failed to control the grape plume moth in home vineyards either when applied especially to kill this insect or in a regular schedule to combat other insect pests of the grape.

The most satisfactory control has been obtained by spraying with oil emulsion or sodium dinitro cresylate to kill the eggs. Oil emulsion was effective when diluted to 3 percent actual oil in the finished spray. Sodium dinitro cresylate was effective when diluted to 1 percent. In both laboratory and field experiments sodium dinitro cresylate was ineffective at a ½ percent dilution, and a 1½ percent dilution was not significantly more effective than a 1 percent dilution. The application should be made about April 15 when the buds are still dormant. No injury to the vines was observed where any of the insecticides was used.

LITERATURE CITED

1. Abbott, W. S. A method of computing the effectiveness of an insecticide. Jour. Econ. Ent. 18 (2) :265-267. 1925.
2. Britton, W. E. The grape plume moth. 14th Rpt. of the State Entomologist of Connecticut (1914):190. 1915.
3. Fitch, Asa. Trans. N. Y. Agr. Soc. XIX:843. 1854.
4. Husmann, Gus C. Grape propagation, pruning and training. U. S. Dept. Agr. Farmers' Bul. 471. 1932.
5. Lintner, J. A. The gartered plume-moth. 12th Rpt. of the State Entomologist on the Injurious and Other Insects of the State of New York for the Year 1896, pp. 218-222. 1896.
6. Muesebeck, C. F. W., and Dohanian, S. M. A study in hyperparasitism, with particular reference to the parasites of Apanteles melanoscelus (Ratzeburg). U. S. Dept. Agr. Dept. Bul. 1487, April 1927.
7. ———— Common names of insects approved by the American Association of Economic Entomologists. 1940.
8. Packard, A. S. Insects injurious to forest and shade trees. 5th Rpt. U. S. Ent. Comm. p. 85. 1890.
9. Pettit, R. H. The principal grape insects of Michigan. Mich Agr. Expt. Sta. Spec. Bul. 239:16. 1933.
10. Quaintance, A. L., and Shear, C. L. Insect and fungous enemies of the grape. U. S. Dept. Agr. Farmers' Bul. 1220:24-25. 1921.
11. Sears, F. C. Grape growing in Massachusetts. Mass. State Col. Ext. Leaf. 64. 1938.
12. Slingerland, M. V., and Crosby, C. P. Manual of fruit diseases. The Macmillan Co. pp. 422-423. 1922.
13. Smith, J. B. Economic entomology. Lippincott & Co. p. 318. 1896.
14. Surface, H. A. Pests and their treatment—The grape plume moth. Pa. Dept. Agr. Bimo. Zool. Bul. 1 (1):35. 1911.
15. Whitcomb, W. D., and Tomlinson, Wm. E., Jr. The grape plume moth. Jour. Econ. Ent. 33 (2):372-374. 1940.

PART II—NOTES ON OTHER PESTS OF GRAPES IN MASSACHUSETTS

By W. D. Whitcomb, Research Professor of Entomology, and E. F. Guba, Research Professor of Botany

Although grapes are not attacked by injurious insects and fungus diseases as severely in Massachusetts as in some parts of the United States, there are several destructive pests which damage the vines and fruit. The more important phases of the life history, habits, and control of these pests are summarized and a spray schedule for the control of grape pests throughout the season is included.

INJURIOUS INSECTS

Rose Chafer—Macrodactylus subspinosus (Fab.)

The rose chafer or "rose bug" is one of the most troublesome and destructive pests of grapes in Massachusetts. The beetle, which is about ½ inch long with yellowish brown wing covers and black head, body, and thorax covered with yellow hairs, is well known and recognized by its long legs and awkward movements. It feeds on the blossoms of a large variety of plants especially rose and peony but has a decided preference for the buds, blossoms, and newly formed fruit of grapes.

The eggs are laid in the sod of sandy soil and the grubs feed on grass roots throughout the summer. Pupation takes place the following spring and the beetles emerge and feed about the time that the grapes are in bloom.

Hand-picking is the most common method of combating the rose chafer on home grapevines but it is a very discouraging task because of the continuous migration of the beetles and the results are often very disappointing. Spraying with lead arsenate at the rate of 5 pounds in 100 gallons of water (4 level tablespoonfuls in 1 gallon) kills many of the beetles and it is more effective if 2 gallons of molasses (2 tablespoonfuls) is added to make the spray more palatable. It should be applied just before the grapes blossom or when the beetles first appear. Various commercial sprays containing rotenone, if used about twice as strong as the usual recommended dilutions, kill those beetles that are thoroughly wet but give little or no protection against beetles which appear 2 or 3 days after spraying.

Grape Berry Moth—Polychrosis viteana (Clemens)

Although it is one of the most destructive insect pests of grape in many grape growing areas, the grape berry moth is seldom destructive in Massachusetts where the over-wintering larvae are killed by low winter temperatures. A few individuals usually survive, however, and provide the source for a more serious infestation in seasons when a warm dry summer follows a mild winter.

The pale brown moth with mottled lighter markings and a wide purplish band on the wings is only ½ inch from tip to tip of the expanded wings.

The moths emerge from the winter cocoons in fallen grape leaves about the time the grapes blossom, and lay eggs in the flower clusters. The larvae of the first generation feed on the blossoms and young grapes and develop into a second generation. The larvae of the second brood feed in ripening berries, often entering several berries before building a winter cocoon in the fold of a leaf.

Control of the grape berry moth is greatly facilitated by regular burning of the fallen leaves in early winter and cultivation under the vines in the spring. The recommended spraying treatment is an application just after the blossom period and again when the young grapes are nearly touching in the cluster, using 1½ pounds of lead arsenate in a 4-4-50 bordeaux mixture. The addition of ½ pint of fish oil or raw linseed oil as a sticker and spreader is very advantageous. These sprays to combat the first generation caterpillars should be applied very thoroughly and carefully because later sprays to combat the second generation caterpillars may leave an undesirable residue and should be avoided if possible.

Grape Leafhopper—Erythroneura comes (Say)

The grape leafhopper is usually present in Massachusetts vineyards but it is not abundant every year. The hoppers suck the plant juices from leaves, giving them a mottled appearance, and badly infested vines usually produce small and poorly flavored fruit. The adult is about 1/8 inch long and very agile, hopping and flying in quick darts or running rapidly in any direction. It is light yellow in color with several red spots and bands which vary in pattern with individuals.

The insect hibernates as the adult, emerging in the spring and laying eggs in the veins on the under surface of the leaves in June. The young nymphs, which are white with red eyes, feed on the leaves until midsummer when they develop into adults. A second brood of nymphs usually develops in September but many of these do not become fully grown before cold weather.

The grape leafhopper is controlled by spraying with 40 percent nicotine sulfate at the rate of 1 pint in 100 gallons, or 1½ teaspoonfuls in 1 gallon. The nicotine sulfate is usually added to bordeaux mixture and lead arsenate to make a combination spray (See Spray Schedule). It is most effective if applied when the nymphs are about one-half grown, usually in late June. It may need to be repeated about Sept. 1 at which time the lead arsenate and bordeaux mixture should be omitted.

Grape Rootworm—Fidia viticida Walsh

The grape rootworm is a potential pest of grapes in Massachusetts but is seldom destructive here. The beetle is small, hairy, and chestnut brown in color. Injury by the beetles consists of chainlike holes eaten in the foliage, and the grubs feed on the roots.

Calcium arsenate or lead arsenate, preferably combined with bordeaux mixture as for grape berry moth, controls the beetles if applied when the adults first appear, soon after the grapes have blossomed.

Brown Grape Aphid—Macrosiphum illinoisensis (Shimer)

This insect attacks the tender growing shoots and leaves, but occasionally it becomes so abundant that the honeydew which is secreted falls on the fruit and makes it sticky and gummy. This aphid spends the winter in the egg stage on the hawthorn from which the winged migrants fly to the grape where seven or eight generations may develop throughout the summer. Ladybird beetles and other natural enemies greatly reduce the populations of the brown grape aphis. It can be well controlled by spraying with 40 percent nicotine sulfate at the rate of 1 pint in 100 gallons.

Grape Flea Beetle—Altica chalybea (Illiger)

In some parts of Massachusetts the grape flea beetle is a destructive pest of grape buds in the early spring. This greenish-blue jumping beetle about 1/5 inch long eats into the buds when they are ready to burst and may materially reduce the crop. The larvae feed on the upper surface of the leaves for three or four weeks during May and June. When the grape flea beetle is abundant, spraying with lead arsenate, 4 pounds in 100 gallons, just before the buds open gives satisfactory control. Usually, however, spraying with arsenicals during the early summer, as for grape berry moth control, kills the larvae and keeps this pest in check.

Grape Cane Girdler—Ampeloglypter ater (Lec.)

The grape cane girdler has become increasingly abundant in eastern Massachusetts since 1938. This tiny black snout beetle makes a ring of punctures around the new cane a few inches from the tip causing it to break and fall or to hang suspended. The egg is usually laid just below the point of girdling and the grub feeds for about a month as a borer in the pith of the new cane. Beetles emerge about the middle of August and go into hibernation under trash soon after. There is one generation annually.

Spraying with lead arsenate prevents the beetles from girdling the canes but the new canes grow so rapidly that applications must be made every three or four days to protect the new growth. Hand-picking of the girdled canes is the usual method practiced. When this is done the cane should be pinched off two or three inches below the point of girdling in order to destroy the egg or grub.

Japanese Beetle—Popillia japonica Newman

In some areas in Massachusetts, especially near the larger cities, the Japanese beetle has become established and grape leaves are one of the favorite foods. The fruit is not attacked. The Japanese beetle is about 3/8 inch long and nearly as wide. It is generally brilliant green in color with reddish brown wing covers and alternate black and white bands or spots on its abdomen. The beetles skeletonize the leaves during July and August but the grubs, which live in the soil, feed on grass roots and are a serious pest of turf.

The recommended treatment is spraying with 6 pounds of lead arsenate and 4 pounds of flour in 100 gallons of water when the beetles appear, but since this may leave considerable residue on the fruit, a repellent spray composed of 20 pounds of hydrated lime and 3 pounds of aluminum sulfate in 100 gallons may be preferred.

DESTRUCTIVE DISEASES

Black Rot—Guignardia bidwellii (Ell.) Viala & Ravaz

Black rot is the most common and destructive disease of grapes in many vineyards. It attacks all green parts of the vine. Infections on the stems, fruit stalks, and leaf veins develop into small sunken cankers which may cause girdling. On the leaves circular reddish-brown spots which grow together cause large irregular dead areas and are dotted with minute black pustules on the upper surface. On the berries infections appear as circular sunken purplish-brown spots, the centers of which are dotted with small black pustules. Infected berries rot, turn black, and dry into wrinkled mummies that are covered with slightly raised black pustules. These pustules are the spore bodies of the fungus. The fungus over-winters in the shriveled berries and the infected parts of the vine.

Downy Mildew—Plasmopara viticola (B. & C.) Berl. & DeToni

Downy mildew develops on all green parts of the vine and on the berries. On the leaves this disease forms yellowish spots which turn reddish brown on the upper surface and eventually die out. A glistening loose white cottony or frost-like growth develops on the lower surface of the leaves. When the disease is severe, the infected leaves and shoots are dwarfed, dry up, become brittle, and fall. Infected berries at first show brownish-purple spots, become hard, and are covered with the cottony or downy fungus similar to that on the leaves. They rot, turn brown, wither, and fall. The fungus hibernates in diseased leaves.

Powdery Mildew — Uncinula necator (Schw.) Burr.

This disease appears at first as pale greenish mottled patches on the leaves, the surfaces of which are covered with a white or grayish powdery mildew. This growth is composed of summer spores which spread and continue the infection throughout the growing season. Badly infected foliage has a musty, moldy odor. Patches of mildew also appear on the new shoots, stems of the fruit clusters and stalks of the individual berries. The infected berries have a gray scurfy appearance and are dwarfed or grow irregularly. In severe cases they may crack open, fail to mature, and drop. Numerous minute black pustules or spore bodies carry the disease over winter on the infected parts of the vine.

Control of More Important Grape Diseases

Black rot, downy mildew, and powdery mildew thrive and cause serious damage only with continuous or excessively moist weather and are controlled by the same treatment.

Vines growing in locations which receive normal sunshine and have good air drainage ordinarily require very little protection with fungicides. If planted in depressions or shaded by trees or buildings, the vines may need the protection of two or more applications of bordeaux mixture or copper dust as indicated in the accompanying Spray Schedule.

Infection of new growth takes place in wet weather from spores which issue from the infected parts of the vine which have over-wintered on the ground or on the trellis. Careful pruning by a recommended system and the destruction of the cut canes and fallen leaves will eliminate many sources of infection and prevent a dense growth of foliage which interferes with drying. During the growing season tall grass and weeds should be cut close to the ground to aid the circulation of air.

On a few vines, choice bunches of grapes can be protected from diseases as well as from insects and birds by enclosing them in a paper bag soon after the berries form. However, it may be necessary to protect the foliage by spraying.

Spray Schedule For Grapes in Massachusetts[1]

Time of Application	Pests	Material	Amount to Use	
			In 100 Gallons	In 1 Gallon
When vines are dormant, usually before April 15	Grape Plume Moth	Sodium dinitro cresylate[2]	1 gallon (1 percent)	1¼ liquid ounces
		OR		
		Oil emulsion	3 gallons (3 percent)	3¾ liquid ounces
When buds are opening	Grape Flea Beetle	Lead arsenate	3 pounds	2¼ tablespoonfuls
Just before blossoms appear	Black Rot Downy Mildew Powdery Mildew	Bordeaux mixture[3]	8-8-10 formula	Powdered copper sulfate, 2 2/3 tablespoonfuls Hydrated spray lime, 6 tablespoonfuls
	Rose Chafer	Lead arsenate Cheap molasses	5 pounds 2 gallons	4 tablespoonfuls 2 tablespoonfuls
When fruit is set	Black Rot Downy Mildew Powdery Mildew	Bordeaux mixture	8-8-100 formula	Powdered copper sulfate, 2 2/3 tablespoonfuls Hydrated spray lime, 6 tablespoonfuls
	Rose Chafer	Lead arsenate Cheap molasses	5 pounds 2 gallons	4 tablespoonfuls 2 tablespoonfuls
	Grape Berry Moth Grape Root Worm Grape Cane Girdler	Lead arsenate[3]	3 pounds	2¼ tablespoonfuls

When grapes are size of peas and touch in cluster	Black Rot Downy Mildew Powdery Mildew	Bordeaux mixture	8-8-100 formula	Powdered copper sulfate, 2 2/3 tablespoonfuls Hydrated spray lime, 6 tablespoonfuls
	Grape Berry Moth Grape Cane Girdler	Lead arsenate	3 pounds	2¼ tablespoonfuls
About two weeks later, or in mid-July	Black Rot Downy Mildew Powdery Mildew	Bordeaux mixture	8-8-100 formula	Powdered copper sulfate, 2 2/3 tablespoonfuls Hydrated spray lime, 6 tablespoonfuls
	Grape Leafhopper Brown Grape Aphid	Nicotine sulfate	1 pint	1½ teaspoonfuls
	Japanese Beetle	Lead arsenate Flour	6 pounds 4 pounds	5 tablespoonfuls 2½ tablespoonfuls

---

[1] Dusts may be substituted for sprays. See note 3.

[2] Commercially known as Elgetol. Similar dinitro insecticides are satisfactory.

[3] Copper dusts containing 5 to 7 percent metallic copper may be used instead of bordeaux mixture. Powdered lead arsenate, equal to 10 percent of the dust by weight, may be added to the copper dust. Any commercial brand of dry bordeaux or neutral copper powder may be used according to the manufacturer's directions as a substitute for bordeaux mixture.

Detailed directions for making bordeaux mixture, and for controlling other grape pests, may be obtained from the Massachusetts State College, Amherst, or from the Waltham Field Station, Waltham.

LIST OF LESS IMPORTANT GRAPE PESTS IN MASSACHUSETTS

Insects

Grape leaf folder—Green caterpillar which eats and folds leaves.
Eight-spotted forester—Striped caterpillar which eats foliage.
Grapevine tomato gall—Small green tomato-like galls on leaves and stems.
Soft Brown Scale—Brown flat scale on canes.
Grape Phylloxera—Gall-like swellings on roots and leaves.

Diseases

Anthracnose—Bird's-eye spots on berries; small brown spots on shoots and leaves.
Dead Arm—Cankers on canes, killing them beyond canker.
Crown Gall—Tumor-like growth on roots and canes.
Ripe Rot—Reddish-brown spots with pinkish spore masses on fruit at ripening.
Bitter Rot—Similar to Ripe Rot but having black spore masses.
Chlorosis—Yellowish sickly leaves due to poor soil conditions.
Failure to Set—Premature dropping due to unfavorable weather or culture.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 410 November 1943

Propagation of the High-Bush Blueberry by Softwood Cuttings

By W. L. Doran and J. S. Bailey

Blueberries are difficult to propagate because the cuttings root so slowly. These experiments were planned to find a method for decreasing the percentage of failures encountered at present.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

PROPAGATION OF THE HIGH-BUSH BLUEBERRY BY SOFTWOOD CUTTINGS

By W. L. Doran, Research Professor of Botany,
and J. S. Bailey, Assistant Research Professor of Pomology

The high-bush blueberry, *Vaccinium corymbosum* L., is usually propagated by hardwood cuttings, a method described in some detail by Bailey et al. (1)*. These cuttings root slowly, however, usually requiring about thirteen weeks at least, and their rooting was not hastened or significantly improved by the root-inducing substances with which Johnston (5) treated them.

Less use has been made of softwood cuttings, although, even without chemical treatment, they can be made to root well if not always very quickly. Principal objects of the present work were to determine the effects of certain factors, i.e., rooting media, treatment of cuttings, and stage of their growth when taken, not only on total percentages rooting but also, and especially, on the time required for the rooting of softwood cuttings.

Relatively little investigational work has been done on the subject previously. Hitchcock and Zimmerman (4) and Doran (3) found that the rooting of June or July cuttings of several varieties of blueberry was improved or that they rooted in larger percentages after treatment with indolebutyric acid, 20 to 40 milligrams or 50 milligrams per liter, but the time factor was not emphasized. O'Rourke (6) concluded from the results of his work that the use of indolebutyric acid in talc is justified with softwood cuttings of blueberry. Chandler and Mason (2) observed no significant responses when they treated "summer" cuttings of several varieties with much lower concentrations of indoleacetic acid or indolepropionic acid. Percentages which rooted were increased by phenylacetic acid but the investigators concluded that the results did not justify the recommendation of a root-inducing substance for use with blueberry cuttings.

In the work now to be described, cuttings of the variety Rubel were taken three times in 1943: first on July 1 when the green berries were one-fourth to three-eighths inch in diameter, again on July 8, and again on July 15 when the first fruit to ripen was almost ready to be picked. All cuttings were made of short side shoots, three to five inches long, with the basal cut at the base of the current season's growth.

The solution–immersion or powder–dip treatments with root-inducing substances were applied to cuttings in the usual way immediately before their insertion in the rooting media. These were either sand or a mixture of equal parts of sand and sphagnum peat. Both were in a glass-covered case in a shaded greenhouse. Cuttings were watered daily, ventilation of the case was kept at a minimum, and temperatures of the rooting media were usually between 70° and 90°F.

In order to determine the effects of the several factors on rapidity of rooting as well as on total percentages rooting, cuttings were examined weekly. Results are recorded in Tables 1, 2, and 3. Treatments which failed to hasten or improve rooting or root growth and treatments which caused injury are not listed in the tables but they are discussed below.

In general, cuttings rooted more rapidly and responded more to treatments if they were taken July 1 than if they were taken later. Untreated cuttings in sand–peat rooted 100 percent in 12 weeks when taken July 1, 48 percent in 15 weeks when taken July 15. Similarly, cuttings treated with Hormodin No. 1 or No. 2 rooted 96 percent in 9 weeks if taken July 1, not more than 64 percent in 15 weeks if taken July 15. The resulting differences between the first (July 1) and second (July 8) experiments and between the second and third (July 15) experiments were smaller but for the most part tended in the same direction, with better results when cuttings were taken earlier. It appears from this that the best time to take softwood cuttings of high-bush blueberry is not later than two to three weeks before the first fruit ripens. Taken then, there was excellent rooting of untreated cuttings, although they rooted more slowly than some of the treated. Cuttings taken later may root slowly and poorly without treatment but, as will be seen, they can be induced to root well and quickly in sand–peat if given certain treatments.

---

*Numbers in parentheses refer to literature cited. See page 8.

In almost every case, rooting was more rapid, root systems were superior, or total percentages rooted were greater in sand–peat than in sand. This was true in five out of six comparisons in the first experiment, three out of three in the second, and seven out of eight in the third. Only in the last experiment, which was begun on July 15 when cuttings were too old or hard for best results in either medium, did untreated cuttings root better in sand than in sand–peat. Sand–peat is plainly to be preferred; and because of the usually inferior rooting in sand, there is even more need for the chemical treatment of cuttings in it than in sand–peat.

Different rooting media require different chemical treatments of cuttings for best results. Cuttings were usually more susceptible to chemical injury by a root-inducing substance in sand–peat than in sand. Injury, if it occurred, was manifested as a breakdown of tissue at the base of the cutting and a lower percentage of cuttings rooting. Treatments injurious to cuttings in sand–peat but not to those in sand were Hormodin No. 3, naphthaleneacetic acid 25 milligrams per liter of water for 22 hours, indolebutyric acid 50 mg./l., 22 hours, and b-naphthoxyacetic acid 25 mg./l., 20 hours. Although there are several treatments which are both safe and effective in sand–peat, root-inducing substances should be used with more caution if sand–peat is to be the rooting medium than if sand is to be used.

It is fortunate, therefore, that cuttings which are to go into sand–peat do not require treatment with as high concentrations, or for so long a time, as do cuttings in sand. Treatments were, in general, of more benefit to cuttings in sand-peat than to those in sand. Treatments which hastened or improved the rooting of cuttings in sand–peat but not in sand included Hormodin No. 1 and naphthaleneacetic acid 50 mg./l., 5 hours, in the first experiment; a-naphthaleneacetamide 4 milligrams per gram of talc in the second; Hormodin No. 2, potassium indolebutyrate 100 mg./l., 5 hours, indolepropionic acid 25 mg./l., 20 hours, and a-naphthaleneacetamide 4 mg./gm. talc in the third.

Certain treatments were either harmful or of relatively no benefit and are, therefore, not listed in the tables. Monobasic potassium phosphate, 0.5 percent solution, 19 hours, caused injury in both sand and sand–peat. Manganese sulphate 0.5 percent solution, 19 hours, was injurious in sand–peat and relatively ineffective in sand. Combination treatments consisting of naphthaleneacetic acid 50 mg./l., 5 hours, followed by a Hormodin gave results no better than or inferior to Hormodin No. 1 or No. 2 used alone. Similarly, treatment with indolebutyric acid 100 mg./l., 5 hours, followed by treatment with Hormodin No. 1 gave results no better or less good than did Hormodin No. 1 alone. Used together, indolebutyric acid 25 mg./l., and naphthaleneacetic acid 12.5 mg./l., 19 hours, hastened rooting no more than did either alone.

TABLE 1.—THE ROOTING OF HIGH-BUSH BLUEBERRY CUTTINGS TAKEN JULY 1.

Treatments	Rooting Media	Percentage of Cuttings Which Rooted in the Number of Weeks Indicated											
		Weeks											
		4	5	6	7	8	9	10	11	12	13	14	15
Check (untreated)	Sand-peat	0	12	56	72	84	92	96	96	**100**			
	Sand	8	12	28	36	48	56	76	80	**88**			
Hormodin No. 1	Sand-peat	8	52	72	76	80	**96**						
Hormodin No. 2	Sand-peat	40	72	76	84	84	**96**						
	Sand	8	28	44	44	48	60	84	88	92	92	**96**	
Hormodin No. 3	Sand	12	48	64	80	88	88	**96**					
Indolebutyric acid													
25 mg./l., 17 hr.	Sand-peat	40	88	92	**100**								
	Sand	12	48	76	80	80	80	84	84	88	92	92	**96**
50 mg./l., 17 hr.	Sand-peat	60	68	84	88	92	96	96	**100**				
	Sand	12	52	68	72	72	80	80	80	**92**			
100 mg./l., 17 hr.	Sand-peat	48	68	68	80	84	84	**92**					
	Sand	32	84	88	88	88	96	**100**					
a-Naphthaleneacetic acid													
12.5 mg./l., 22 hr.	Sand-peat	32	68	80	92	**96**							
	Sand	32	52	64	64	68	84	92	92	92	96	96	**100**
25 mg./l., 22 hr.	Sand	20	52	64	68	68	68	72	72	88	88	88	**92**
50 mg./l., 5 hr.	Sand-peat	12	40	68	84	**100**							

Figures in boldface are percentages which had rooted when no unrooted cuttings remained.

TABLE 2.—THE ROOTING OF HIGH-BUSH BLUEBERRY CUTTINGS TAKEN JULY 8.

Treatments	Rooting Media	Percentage of Cuttings Which Rooted in the Number of Weeks Indicated											
		Weeks											
		5	6	7	8	9	10	11	12	13	14	15	16
Check (untreated)	Sand-peat	0	8	40	52	72	80	80	88	88	**96**		
	Sand	0	8	20	20	40	40	40	40	48	48	72	84
Hormodin No. 1	Sand-peat	24	60	92	96	**100**							
	Sand	0	40	44	44	44	44	44	48	52	52	52	76
Hormodin No. 2	Sand-peat	48	48	64	68	76	76	80	80	80	**84**		
	Sand	0	12	24	32	32	52	64	64	68	68	72	72
Hormodin No. 3	Sand	12	24	48	52	52	64	64	64	68	68	72	80
Indolebutyric acid													
50 mg./l., 22 hr.	Sand	8	24	24	52	52	60	60	68	68	76	80	88
a-Naphthaleneacetic acid													
25 mg./l., 22 hr.	Sand	8	16	36	44	44	60	64	64	64	64	76	80
a-Naphthaleneacetamide													
4 mg./gm. talc	Sand-peat	8	40	60	88	88	88	92	92	92	**96**		

Figures in boldface are percentages which had rooted when no unrooted cuttings remained.

TABLE 3—THE ROOTING OF HIGH-BUSH BLUEBERRY CUTTINGS TAKEN JULY 15.

Treatments	Rooting Media	Percentage of Cuttings Which Rooted in the Number of Weeks Indicated											
		Weeks											
		5	6	7	8	9	10	11	12	13	14	15	16
Check (untreated)	Sand-peat	0	0	8	8	16	16	16	36	40	40	**48**	
	Sand	0	16	24	40	40	40	40	40	40	64	64	68
Hormodin No. 2	Sand-peat	20	28	36	52	56	56	56	56	60	60	**64**	
Indolebutyric acid													
50 mg./l., 20 hr.	Sand-peat	20	32	60	76	76	76	**80**					
	Sand	8	24	24	52	52	52	56	56	56	60	60	64
100 mg./l., 5 hr.	Sand-peat	32	40	48	56	56	56	64	64	72	72	**76**	
	Sand	0	40	40	52	52	64	64	64	72	72	76	76
a-Naphthaleneacetic acid													
12.5 mg./l., 20 hr.	Sand-peat	32	60	60	76	76	76	**80**					
25 mg./l., 20 hr.	Sand-peat	28	56	64	80	80	80	**84**					
	Sand	24	48	68	68	76	76	76	76	80	80	84	84
50 mg./l., 20 hr.	Sand-peat	28	52	56	72	72	72	72	**80**				
Potassium indolebutyrate													
25 mg./l., 20 hr.	Sand-peat	16	24	44	64	76	76	80	**92**				
	Sand	0	16	16	56	64	80	80	80	84	84	84	92
50 mg./l., 20 hr.	Sand-peat	32	48	76	**88**								
	Sand	0	48	64	80	84	84	84	84	84	92	92	92
100 mg./l., 5 hr.	Sand-peat	24	36	48	72	76	76	84	**92**				
b-Indole-3-propionic acid													
25 mg./l., 20 hr.	Sand-peat	72	76	80	88	88	88	88	**92**				
50 mg./l., 20 hr.	Sand-peat	72	76	76	80	84	84	84	**88**				
	Sand	48	56	60	68	68	68	68	68	68	68	72	80
100 mg./l., 5 hr.	Sand-peat	44	64	84	**96**								
	Sand	40	48	56	72	80	84	84	84	84	84	88	92
a-Naphthaleneacetamide													
4 mg./gm. talc	Sand-peat	12	12	12	12	60	60	60	60	64	64	**68**	
b-Naphthoxyacetic acid													
25 mg./., 20 hr.	Sand	0	40	40	52	56	72	80	**84**				

Figures in boldface are percentages which had rooted when no unrooted cuttings remained.

Rooting was hastened by b-naphthoxyacetic acid in the last experiment, but indolepropionic acid gave even better results. Rooting in the experiment which began July 8 was hastened by a-naphthaleneacetamide 4 mg./gm., talc (8 mg./gm. talc was injurious) in sand-peat, but Hormodin No. 1 was more effective in that experiment and, as is shown in Table 3, several treatments were more effective in the next.

There was no one treatment which was always superior to all others in hastening rooting, increasing total percentages which rooted, and improving the root system. The response was affected by the stage at which cuttings were taken and by the choice of rooting medium; but in all experiments, in both sand and sand-peat, cuttings responded to treatment with some root-inducing substance. These are now named in order of excellence, the best first.

	In Sand-Peat	*In Sand*
Experiment 1 (July 1)	Indolebutyric acid 25 mg./l., 17 hours Naphthaleneacetic acid 12.5 mg./l., 22 hours, or 50 mg./l., 5 hours Hormodin No. 2	Indolebutyric acid 100 mg./l., 17 hours Hormodin No. 3 Naphthaleneacetic acid 12.5 mg./l., 22 hours
Experiment 2 (July 8)	Hormodin No. 1 a-Naphthaleneacetamide 4 mg./gm. talc	Hormodin No. 3 Indolebutyric acid 50 gm./l., 22 hours
Experiment 3 (July 15)	Indolepropionic acid 100 mg./l., 5 hours, or 25 mg./l., 20 hours Potassium indolebutyrate 50 mg./l., 20 hours Indolepropionic acid 50 mg./l., 20 hours	Indolepropionic acid 100 mg./l., 5 hours Potassium indolebutyrate 50 mg./l., 20 hours, or 25 mg./l., 20 hours

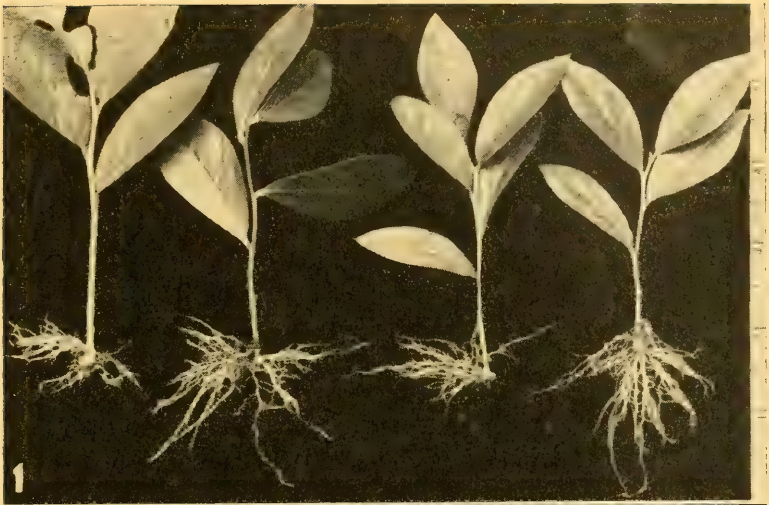
Especially noteworthy were the results obtained with potassium indolebutyrate and indolepropionic acid, particularly the latter, when applied to cuttings taken in mid-July. With these cuttings, made of wood too old to root well without treatment, indolepropionic acid gave better results than either indolebutyric or naphthaleneacetic acid. At the end of five weeks, when untreated cuttings had not even begun to root, there was 40 to 72 percent rooting of cuttings treated with indolepropionic acid (see Table 3), and excellent root systems had already developed (see Figure 1).

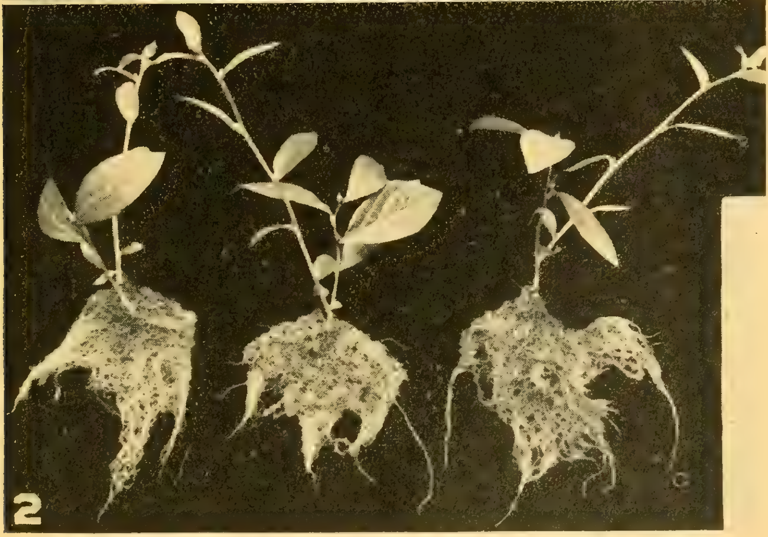
Hormodin No. 3 gave good results in sand but Hormodin No. 1 or No. 2 is safer in sand–peat. Cuttings set in sand–peat on July 1 rooted well without treatment and, under these circumstances, Hormodin No. 1 and No. 2 were about equally, although not strikingly, effective in hastening rooting. In the experiment which was begun July 8, there was more response in sand–peat to Hormodin No. 1, and in the last experiment cuttings were apparently too old to respond markedly to either.

Naphthaleneacetic acid 12.5 mg./l., 17 or 20 hours, gave good results in sand–peat but not so good as did some of the other root-inducing substances. There was no evidence that it is superior to indolebutyric acid for use with softwood cuttings of blueberry.

With cuttings in sand–peat, indolebutyric acid 25 mg./l., 17 hours, gave good results in the first experiment, but in the second experiment, the same treatment continued for 22 hours caused injury. Cuttings in the third experiment, a little less soft, were uninjured by indolebutyric acid 50 mg./l., 20 hours, and their rooting was hastened although less than by indolepropionic acid or potassium indolebutyrate. With cuttings in sand, indolebutyric acid 100 mg./l., 17 hours, was of benefit in the first experiment, 50 mg./l., 22 hours, in the second. No treatment with indolebutyric acid in the third gave results equal to those obtained with some of the other treatments.

There was good and immediate growth of both roots and new shoots when rooted cuttings were transplanted to a mixture of equal parts of sand, peat, and loam or a mixture of equal parts of sand and peat. Cuttings which rooted last or which failed to root by mid-October showed signs at that time of approaching dormancy, their leaves falling or changing to red and yellow in color. Cuttings which had rooted earliest were still green and making new shoot growth in the greenhouse November 1 (see Figure 2).





Cuttings Taken on July 15 and Treated with Indolepropionic Acid.

Figure 1. Five weeks after treatment.

Figure 2. On November 1. The longer branch in each case is new growth made after the cutting rooted.

From these results, the following conclusions are drawn. For the propagation of high-bush blueberry by softwood cuttings, a mixture of sphagnum peat and sand in equal parts is to be preferred to sand as the rooting medium. If cuttings are to be used untreated, they should be taken not later than two to three weeks before the first berries ripen. Whether taken then or later, and especially if taken later, up to the time that the first berries ripen, the rooting of cuttings is sufficiently hastened by root-inducing substances to warrant their use. Indolebutyric acid, applied by solution-immersion or powder-dip, is effective with cuttings taken early, less so or not at all with those taken later. Indolepropionic acid, used only in the last experiment, is certainly to be preferred for cuttings taken relatively late.

Literature Cited

1. Bailey, John S., Franklin, Henry J., and Kelley, Joseph L. Blueberry culture in Massachusetts. Mass. Agr. Expt. Sta. Bul. 358, 20 pp. 1941.
2. Chandler, F. B., and Mason, I. C. The effect of growth substances on the rooting of blueberry cuttings. Science 92:2375:35. 1940.
3. Doran, William L. The propagation of some trees and shrubs by cuttings. Mass. Agr. Expt. Sta. Bul. 382, 56 pp. 1941.
4. Hitchcock, A. E., and Zimmerman, P. W. Comparative activity of root-inducing substances and methods for treating cuttings. Boyce Thompson Inst. Contrib. 10:461-480. 1939.
5. Johnston, Stanley. The influence of certain hormone-like substances on the rooting of hardwood blueberry cuttings. Mich. Agr. Expt. Sta. Quart. Bul. 21:4:255-258. May 1939.
6. O'Rourke, F. L. The effect of indolebutyric acid in talc on rooting of softwood cuttings of blueberries. Amer. Soc. Hort. Sci. Proc. 42:369-370. 1943.

3M-2-44.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

AUG 2 1944

Bulletin No. 411 January 1944

Variability in Egg Weight in Rhode Island Reds

By F. A. Hays

Market grades of eggs are based largely on weight, and it is important, therefore, for the breeder to know how much variability in egg weight may be considered normal and how much is due to genetic factors.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

VARIABILITY IN EGG WEIGHT IN RHODE ISLAND REDS

By F. A. Hays
Research Professor of Poultry Husbandry

Introduction

In recent years the problem of egg size as measured by weight has been of vital concern to poultry breeders. Since weight plays a major role in the development of market grades of eggs, it is easy to understand that both breeder and consumer are concerned. Grades of eggs are built around the two-ounce egg as a standard. Before the present era, when most flocks were not bred for high egg production and when the average annual egg production was below 75 eggs for each hen, a mean egg weight of 24 ounces to the dozen prevailed.

During the past two decades there has been an immense increase in the number of flocks that are selectively bred for high egg production. Ten years ago the average egg production for the United States was 85. In 1942 this average had been raised to 113, and this year the average will probably be higher. As might be anticipated, there has been a tendency for egg size to decline as the number of eggs increased. At the present time this undesirable decrease in egg size has been overcome by selective breeding, but egg size still remains an important character to be watched by the breeder.

Studies on egg size by many investigators including Atwood (1923), Jull (1924), Jull and Godfrey (1933), Marble (1931), Hays (1930), Funk and Kempster (1934), Jeffrey (1938), Clark (1940) and many others have shown that egg size fluctuates widely during the pullet laying year. This is particularly important because most of the eggs produced come from pullet layers. In carrying on a breeding program for egg production it becomes very important that the breeder be able to regulate egg size by breeding and by hatching date to satisfy market demands.

The study presented in this report was undertaken for the purpose of determining normal variability in egg weight for Rhode Island Reds bred for high egg production.

Available Data

Rhode Island Red birds that had been bred for high egg production were used exclusively in this study. Six generations hatched from 1936 to 1941 and consisting of 790 individuals are included. These birds exhibited far superior egg size to those used in our 1930 study.

Changes in Egg Weight During the Pullet Laying Year

In 1930, data on Rhode Island Reds were reported from this laboratory showing that egg weight in the first laying year increased at a nearly constant rate from October through February. It was shown at that time that the maximum egg weight of the first laying year was attained in February when the average age of the birds was from ten to eleven months. During the summer months there was something of a decline in egg size, which persisted until near the end of September when mean egg weight approached the February level. These data are illustrated graphically in Figure 1 taken from the original report.

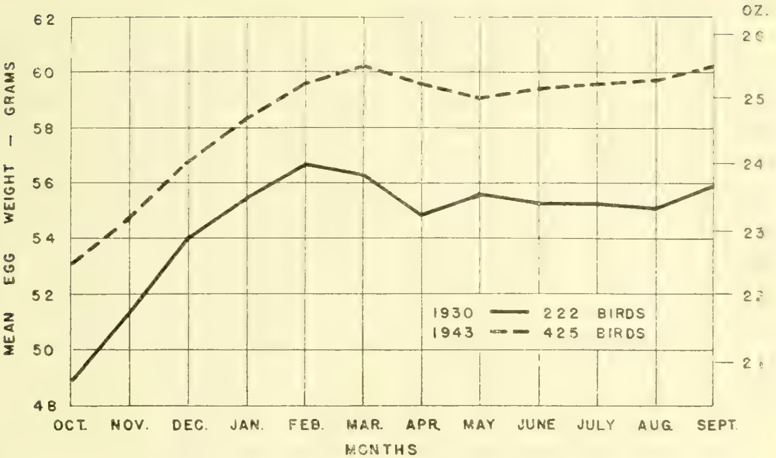


Figure 1. Mean Monthly Egg Weight for the Pullet Year.
(Grams per egg and ounces per dozen.)

Individual Variability in Egg Weight

The standard deviation of a population gives a very satisfactory measure of the variability of that population for a particular character. In the case of egg size it furnishes a good criterion of the relative uniformity in egg size at different periods of the year and for birds of varying ages. Such information is often of more value to the breeder than knowing the population means at different ages or periods.

In table 1 the mean monthly egg weight and the monthly standard deviation of the population are set forth.

TABLE 1.—MEAN MONTHLY EGG WEIGHT AND MONTHLY VARIABILITY IN EGG WEIGHT.
(Measured by the standard deviation.)

Month	Number of Birds	Mean Egg Weight Grams	Standard Deviation in Egg Weight Grams
October	378	53.1	±4.63
November	402	54.8	±4.90
December	397	56.8	±4.89
January	355	58.3	±4.49
February	369	59.6	±4.50
March	376	60.2	±4.52
April	425	59.6	±4.55
May	425	59.1	±4.25
June	419	59.4	±4.34
July	412	59.6	±4.49
August	394	59.7	±4.34
September	370	60.2	±4.54
Mean		58.36*	

*24.7 ounces to the dozen.

A study of table 1 indicates that egg size increased very rapidly from October to March, with the most rapid rate of increase during the months of October, November, and December. After this period there was a slowing up in the rate of increase which was most pronounced during the month of March. These data are illustrated graphically in figure 1 together with the data reported earlier (Hays, 1930). In the earlier studies, when egg size in the flock was small, egg weight was highest in February, lowest in April, and remained at a low level through August. In the later studies, when large egg size prevailed in the flock, egg size showed the greatest decline in May, began to increase in June, and had returned completely to the spring maximum by the end of September.

As already indicated, egg size plays a very important part in meeting market demands. The average behavior of egg size in pullets hatched in March and April is well illustrated in table 1 and figure 1. The fact is very evident that in order to balance the period of about two months when egg size falls below 24 ounces to the dozen, breeders must use earlier-hatched pullets or old hens. When egg size has attained the high level indicated in table 1 (24.7 ounces to the dozen for the year), the period of small eggs is rather short. On the other hand, if egg size is not much above the 24-ounce level during the early spring months, there will be a long period when eggs weigh less than 24 ounces to the dozen.

The data in table 1 also indicate that if a flock is to be evaluated for egg size this should be done at about the age of eleven months. If egg weight records are made at this age, the maximum for the pullet laying year will be recorded and, furthermore, variability in egg size will be near a minimum. The fact is also very evident that the 24-ounce standard applies only for limited periods during the pullet laying year.

Monthly variability in egg size was determined by calculating the standard deviation of the individual monthly mean egg weights. Variability in egg size was high during October, November, and December. In January, February, March, and April variability was lower but constant for the four months. In May there was a further decline in variability that persisted through August. In September the variability returned to the level of early spring. In general, these data appear to indicate that the variability in egg size is greatest when egg size is increasing rapidly and lowest when egg size reaches its maximum in early spring.

Atwood has also used standard deviation as a measure of variability in egg weight as related to season of the year. His data, however, are not comparable with ours because the records did not begin until December and because a different basis was used in calculating the standard deviation. Atwood used the individual egg weights as the unit, instead of the individual monthly mean egg weight, which was the unit used in this study.

Individual Variability in March Egg Weight

The month of March of the pullet laying year offers a close approach to the period of maximum egg weight in the first year for the Rhode Island Reds used in this study. During March the mean age of the pullets is approximately eleven months. March is also a very important month from the standpoint of reproduction and it offers the breeder an opportunity to select for maximum egg size in breeding pullets that are hatched in March and April.

The standard deviation in egg weight for the month of March was calculated on each individual pullet of the total 765. These values have been summarized in a frequency table to discover the character of distribution as well as the mode and the mean.

The mean March standard deviation in egg weight for the population was 2.05 grams. This mean is higher than the mode, which was 1.75 grams. It is evident, therefore, that the distribution is slightly skewed. The fact that essentially all of the population falls below a standard deviation of 4.5 grams indicates that variability in egg weight is at a low level during March, which is an important reason why selection for egg size during March of the pullet year is to be recommended.

The frequency distribution of March variability in egg weight, though slightly skewed, is close enough to a normal frequency distribution to be considered normal. This fact suggests that inherited variability in egg weight may almost completely disappear at this time.

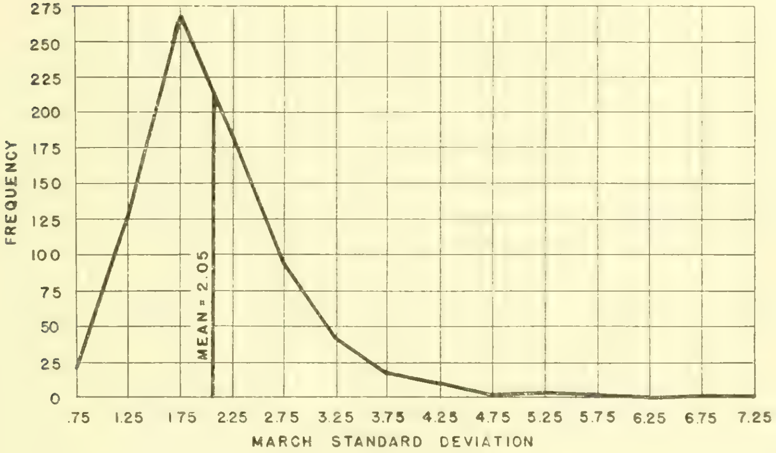


Figure 2. Frequency Distribution of March Variability — 765 Birds.

The Relation of Fecundity Characters to Variability in Egg Weight

Inherited characters affecting egg production are widely recognized by poultrymen since they have been extensively discussed in the literature. Flocks that are bred for high egg production are bred for uniformity in these characters. It is important to know, therefore, whether these characters are in any way related to the variability in egg weight.

Correlation Between Annual Variability in Egg Weight and Age at First Egg

Individual variability in egg weight was measured by the standard deviation between the means of the twelve months of the first laying year. The age at first egg was recorded in days. Data are available on 423 individuals from which the following constants were calculated:

Number of birds	423
Mean annual variability in egg weight, grams	2.81
Standard deviation of annual variability	±1.00
Mean age at first egg, days	188.45
Standard deviation of age at first egg	±21.50
Coefficient of correlation	− .3084 ± .0297
Correlation ratio	.4940

The data show a mean variability in egg weight between the months of 2.81 grams, which is much lower than that recorded within any one month as shown in table 1. This fact indicates that the variation within the lot of eggs laid during any one month is greater than the variation between the twelve monthly egg weight means. The standard deviation of the annual variability was 1.0 gram and may be considered very large. Age at first egg is a rather stable genetic character as shown by the mean of 188.45 days, with a standard deviation of only 21.5 days.

The simple correlation between age at first egg and annual variability in egg weight was −.3084 ± .0297. However, the regression of variability on age was found to be non-linear so that the correlation ratio, .4940, expresses the association. This is a rather intimate relationship and indicates that the younger the pullet is when she lays her first egg, the greater the variability in egg weight between the twelve months of the first laying year. This higher variability in the earlier maturing pullets is probably due in part to the fact that such birds are likely to start their year with small egg size (Hays, 1930). These data further support the idea that extreme early maturity is not desirable from the standpoint of the character of eggs produced.

Correlation Between March Variability in Egg Weight and Age at First Egg

As already pointed out, egg weight in this flock reached its maximum for the first year during March, and variability in egg weight was at a low level at this particular time. It is therefore important to know whether there is any correlation between the variability in egg size that occurs in March and age at first egg. In this study the individual variability in egg size was measured by the standard deviation within the month and is not the same constant that was recorded in table 1.

Regression was linear and the following constants were calculated:

Number of birds	754
Mean March variability in egg weight, grams	2.05
Standard deviation of March variability	±.75
Mean age at first egg, days	192.25
Standard deviation of age at first egg	±23.37
Coefficient of correlation	.0080 ± .0246

The population was larger in this study than in the previous section because many individuals had a March egg weight record but lacked other months in the first laying year.

The coefficient of correlation between March variability and age at first egg is essentially zero, showing that there was no association between age at sexual maturity and variability in egg weight within the month of March.

Correlation Between Annual Variability in Egg Weight and Winter Clutch Size

Winter clutch size is a good measure of intensity, as was pointed out by Hays and Sanborn (1927, 1932). Data have also been presented (Hays and Sanborn, 1927) showing that winter clutch size behaves as an inherited character. The net correlation between winter clutch size and annual egg production is also very significant, .4944 ± .0101 (Hays and Sanborn, 1927a), making this a very important character to breed for.

The correlation between annual variability in egg weight and winter clutch size will indicate whether or not the rate of laying affects the variability in egg weight. The following constants were calculated:

Number of birds	419
Mean annual variability in egg weight, grams	2.81
Standard deviation of annual variability	±1.00
Mean winter clutch size, eggs	2.99
Standard deviation of winter clutch size	±1.23
Coefficient of correlation	−.0584 ± .0328

The mean annual variability in egg weight between the twelve months was 2.81 grams. There is, however, a considerable variation here as shown by a standard deviation of 1.00.

Mean winter clutch size of the population was 2.99 eggs, which places most of the population in the high intensity phenotype. The variability of the population with respect to clutch size was very high, amounting to about 40 percent as measured by the coefficient of variation. This conforms to previous observations that intensity as measured by winter clutch size is extremely variable.

The coefficient of correlation between annual variability and winter clutch size was very small and amounted to less than twice its probable error. Regression was tested and found to be linear, so that the data indicate no relation between the winter rate of laying and the variability in egg weight between the months.

Correlation Between March Variability in Egg Weight and Winter Clutch Size

As previously pointed out, variability in egg weight was at a low level in the month of March. The maximum egg weight of the first laying year also appeared in March, making this month a good time to record the egg weight for the flock as a whole. It seems desirable, therefore, to determine the correlation between March variability in egg weight and winter clutch size. The following are the resulting constants:

Number of birds	750
Mean March variability in egg weight, grams	2.05
Standard deviation of March variability	±.75
Mean winter clutch size, eggs	3.12
Standard deviation of winter clutch size	±1.24
Coefficient of correlation	−.0509 ± .0246

Regression of March variability on winter clutch size was found to be linear. The correlation between March variability in egg weight and winter clutch size was of such small magnitude as to be insignificant. This fact indicates that the variability in egg weight for the month of March is not associated with differences in the rate of laying during the winter season.

Relation of Annual Variability in Egg Weight to Winter Pause

Winter pause, as used in these studies, includes a cessation of egg laying for eight or more days between November 1 and March 1 of the pullet laying year. Both time of onset and duration of pause are believed to be affected by environmental influences. Evidence was presented in 1924 by Hays, indicating that a major inherited factor for pause was operating. Data were presented later (Hays, 1936) to indicate that the minimum period of non-production associated with inherited winter pause was about eight days. Lerner and Taylor (1939), using White Leghorns, confirmed the observations from this laboratory on Rhode Island Reds. These workers used a cessation in laying of seven or more days between November 1 and March 1 as winter pause.

The Rhode Island Red females used in these studies were grouped into the "pause" class if they had shown a cessation in egg production of eight or more successive days between November 1 and March 1. Those individuals which did not exhibit a winter pause were grouped into the "non-pause" class.

The standard deviation in egg weight for the first twelve months of laying was calculated on 273 individuals with winter pause and showed a mean annual variability in egg weight of .99 grams with a standard deviation of .029. The corresponding figures for a population of 145 birds without winter pause were 1.03 ± .041 grams. The difference between the two populations amounted to only .04 ± .05 grams, which has no significance. These data furnish some evidence that winter pause bears no relation to variability in egg weight during the first laying year.

Relation of March Variability in Egg Weight to Winter Pause

March variability in egg weight for 412 "pause" birds was .77 grams with a standard deviation of .018; and for 337 "non-pause" birds, .72 ± .019 grams. The difference was .05 ± .026 grams and has no significance. These data indicate that the presence or absence of winter pause has no effect on the variability in egg weight during the month of March.

Relation of Annual Variability in Egg Weight to the Broody Instinct

Goodale, Sanborn and White (1920) have shown the broody instinct to be inherited, and these observations were confirmed by Hays (1924) and many other workers. Hays and Sanborn (1934) presented data covering a 22-year period, indicating that Rhode Island Red pullets average to lose about fifteen laying days at each broody period. Jull (1940) reported that 494 non-broody Rhode Island Reds averaged 204.78 eggs compared with 179.65 eggs for 447 broody birds.

In breeding operations there is a constant attempt to eliminate the broody instinct from the flock. This procedure has been effective in reducing the incidence of broodiness during the first laying year to as low as 2 percent, but never in completely eliminating the broody instinct in any breed.

In this study it is desirable to know whether the presence or absence of the broody instinct affects the variability in egg weight. The population was divided into broody and non-broody on the basis of their first-year records, and the variability in egg weight records studied.

The mean annual variability in egg weight for 10 broody birds for the first laying year was .70 ± .106 grams; and for 383 non-broody birds, the figure was .99 ± .024 grams. The difference in the variability of the two groups was .29 ± .108 grams and is of doubtful significance.

Relation of March Variability in Egg Weight to the Broody Instinct

The mean March variability in egg weight for 18 broody birds was .87 grams with a standard deviation of .097; the figure for 568 non-broody birds was .72 ± .015 grams. There was a difference of .15 ± .097 grams which has no significance. These data furnish some evidence that variability in egg weight at any time of year is not affected by the broody instinct.

Correlation Between Annual Variability in Egg Weight and Persistency

Hays (1927, 1936a) has shown high persistency to be inherited and to depend in inheritance upon a single dominant gene. Hays and Sanborn (1927a) showed high persistency to be the most important single inherited character affecting egg production. Knox, Jull and Quinn (1935) also found that high persistency was the most important character affecting egg production. Lerner and Taylor (1937) considered age at last egg to be the best measure of persistency and persistency the most important character affecting annual egg production.

It is obvious, therefore, that high persistency is one of the most desirable characters to breed for; hence it is important to know whether variability in egg weight is in any way related to the length of the laying year.

The correlation between annual variability in egg weight and length of the first laying year was determined, giving the following constants:

Number of birds	393
Mean annual variability in egg weight, grams	2.85
Standard deviation of annual variability	±.99
Mean persistency, days	346.48
Standard deviation of persistency	±33.60
Coefficient of correlation	−.0217 ± .0340

The mean persistency was about 346 days, with a standard deviation of about 34 days. This is a rather small variability for a character of this nature and indicates that high persistency was very well established in this population.

The coefficient of correlation was negative and of no significance even though regression was linear. These data indicate that variability in the length of the laying year is not associated with annual variability in egg weight.

Correlation between March Variability in Egg Weight and Persistency

For the purpose of studying variability in egg weight within a month in relation to persistency, the month of March has been chosen. The correlation between March variability in egg weight and persistency was determined, and gave the following:

Number of birds	586
Mean March variability in egg weight, grams	2.05
Standard deviation of March variability	±.73
Mean persistency, days	343.54
Standard deviation of persistency	±32.98
Coefficient of correlation	−.0537 ± .0278
Correlation ratio	.1956

Regression of March variability on persistency was non-linear, so that the correlation ratio measures the association. The correlation ratio is of the negative order and has a value of about .20 which means that only about 4 percent of the March variability in egg weight can be associated with variability in the length of the laying year.

Summary

Relations between both annual and March variability in egg weight have been studied in the ten previous sections of this report.

A rather intimate negative correlation was observed between age at first egg and annual variability in egg weight, indicating that the pullets that begin laying earliest are likely to show the greatest annual variation in egg weight. No correlation, however, was observed between age at first egg and March variability in egg weight.

No correlation of significance was discovered between winter clutch size and either annual or March variation in egg weight.

Annual and March variability in egg weight were essentially equal in the pause and non-pause populations; and in the broody and non-broody populations.

Annual persistency and annual variation in egg weight were independent; but birds showing highest persistency had a slight tendency to exhibit lower variability in egg weight for the month of March.

Relation of Position of Egg in Clutch to Variability in Egg Weight

The relation of position of egg in the clutch was first studied by Atwood and Weakley (1917) using White Leghorns. These workers reported that the first egg of the clutch was generally heavier than later eggs but that in large clutches the rate of decrease was relatively slower than in small clutches. Jull (1924) confirmed these observations using Barred Plymouth Rocks. Funk and Kempster (1934) likewise obtained similar results with White Plymouth Rock pullets. Hays (1934) pointed out that birds laying at a high rate required a longer period to attain standard egg weight than those laying in smaller clutches.

The relation of the position of the egg in the clutch throughout the first laying year to variability in egg weight has been studied in this report. The data are tabulated below:

TABLE 2.—RELATION OF POSITION OF EGG IN THE CLUTCH TO EGG WEIGHT AND VARIABILITY.

Position of Egg in the Clutch	Number of Eggs	Mean Egg Weight Grams	Standard Deviation in Egg Weight Grams
1	4409	62.0	±4.95
2	3382	61.0	±4.58
3	2135	60.7	±4.46
4	1099	60.2	±4.56
5 or higher	1672	59.4	±4.14

These data confirm the observation of workers with other breeds that the first egg of the clutch is likely to be the heaviest and that as the clutch size increases, the mean egg weight declines at a slower rate. The data also furnish evidence that eggs laid in very large clutches throughout the year are less variable in weight than those laid in smaller clutches.

Inherited Variability in Egg Weight

The correlation between mothers and daughters in March variability in egg weight may be used as an estimation of inherited variability. The standard deviation in March egg weight was calculated for each family of three or more daughters. These values were paired against the March variability in egg weight of the respective dams. The following constants appeared:

Number of families	670
Dam's mean March variability in egg weight, grams	2.07
Standard deviation of dams' March variability	±.81
Mean March variability in egg weight of families, grams	2.04
Standard deviation of March variability of families	±.71
Coefficient of correlation	.0617 ±.0260

The variability in egg weight was essentially the same for the dams and their families of daughters. The standard deviation was slightly lower for families than for dams, as might be expected. The regression was linear, but the small value of the coefficient of correlation fails to suggest inherited variability in egg weight between mothers and daughters.

Variability in Egg Weight of Daughters from Dams of Different Classes with Respect to March Variability in Egg Weight

If variability in egg weight during the month of March is inherited, there should be parallelism between the dams and daughters with respect to this variability. In table 3 the dams are classified with respect to March standard deviation in egg weight, and opposite each class of dams is placed the mean family standard deviation of daughters from the different classes. Figure 3 presents the data graphically.

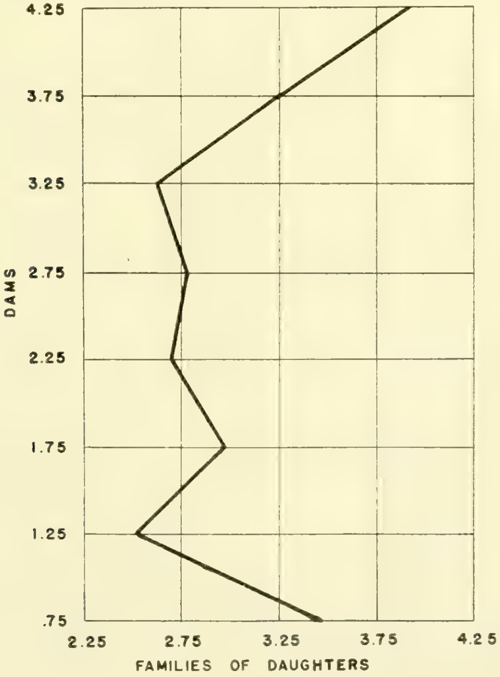


Figure 3. March Variability in Egg Weight of Dams and Their Families (119).

These data for March variability in egg weight show no parallelism between mothers and daughters for classes of dams below the 3.25-gram group. For the three groups of dams showing the extreme variability of 3.25, 3.75, and 4.25, respectively, there is marked parallelism between mothers and daughters. These three classes of dams produced 9, 4, and 3 families, respectively, out of the total of 119 families. These limited data further substantiate the idea that most of the variability in egg weight that appeared in March is non-genetic in character.

Table 3.—Classes of Dams and of Families of Daughters with Respect to March Standard Deviation in Egg Weight.

March Standard Deviation of Dams Grams	March Standard Deviation of Daughters Grams
±0.75	±3.46
±1.25	±2.51
±1.75	±2.97
±2.25	±2.70
±2.75	±2.78
±3.25	±2.63
±3.75	±3.25
±4.25	±3.91

Correlation Between Annual Variability in Egg Weight and Annual Egg Production

Individual annual variability in egg weight was correlated with the individual annual egg record to discover whether the number of eggs laid affected the variability in egg weight. The following constants were calculated:

Number of birds	393
Mean annual variability in egg weight, grams	2.85
Standard deviation of annual variability	±.99
Mean annual egg production	208.07
Standard deviation of annual egg production	±41.53
Coefficient of correlation	−.1970±.0327

Regression was found to be linear, and the coefficient of correlation (−.1920 ±.0327) indicates that only about 4 percent of the variation in egg weight for the year was associated with variation in the number of eggs.

Correlation Between Body Weight at First Egg and Annual Egg Weight

Evidence has been presented by a number of investigators to indicate that the body weight of pullets when they lay their first egg has an important relationship to the size of eggs laid at the beginning of the laying year and to the length of the period required to attain the 24-ounce level. Data have also been presented by many investigators to show that mean body weight of the first laying year is rather intimately correlated with egg weight. The relation between weight at first egg and the mean weight of all eggs laid during the year has been less extensively studied. Data now available for a six-year period throw some light on this problem. The following constants were calculated from these data:

Number of birds	416
Mean weight at first egg, pounds	5.81
Standard deviation in weight at first egg	±.55
Mean annual egg weight, grams	58.30
Standard deviation in egg weight	±4.08
Coefficient of correlation	.1098 ± .0327

The Rhode Island Reds used in these studies were large birds with a mean weight of 5.81 pounds at about 190 days of age. Variability in body weight was not excessive and did not exceed 10 percent. The population also showed large egg size, with an average for the year of 58.4 grams (24.7 ounces to the dozen) and a variability of about 7 percent.

The coefficient of correlation between body weight and annual egg weight was only .1098 ± .0327 and barely significant. It seems evident, therefore, that body weight taken at sexual maturity is a very poor criterion for predicting egg size during the first laying year.

Correlation Between Body Weight at the End of the First Laying Year and Annual Egg Weight

The weights of females at the end of the first laying year are dependent largely upon the mature weight attained at about eleven months of age and the physical condition of the birds. Satisfactory weight at this time is important economically and it is, therefore, desirable to know whether it is correlated with the egg size of the first laying year. The following constants were calculated:

Number of birds	422
Mean weight at end of first laying year, pounds	6.28
Standard deviation in weight at end of laying year	±.83
Mean annual egg weight, grams	58.32
Standard deviation in egg weight	±4.11
Coefficient of correlation	−.0578 ± .0327
Correlation ratio	.2312

Referring back to the previous section, it will be noted that there was an increase of .47 pound between the mean weight at first egg and the mean weight at the end of the laying year. The variability in weight was significantly greater at the end of the year than at the beginning — a condition due largely to variability in the effect on the birds of a year of laying.

Regression of annual egg weight on body weight at the end of the year was non-linear, so that the correlation ratio is used to express the association. This constant is of a negative order and is significant, indicating that those birds which lay the largest eggs for the year are more likely to be depleted in body weight at the close of the laying year.

Effect of Age on Egg Weight and Variability in Egg Weight

The work of many investigators as summarized by Jull (1940) indicates that egg weight during the second laying year is from 4 to 8 percent above that of the first laying year. This observation is also in agreement with early observations from this laboratory. The bulk of published data also indicates that there is very little change in egg weight after the second laying year.

Four different groups of females were studied to determine the effect of age on egg weight and variability in egg weight. The data are summarized in Table 4, and show that a 4 to 5 percent increase in egg weight from the first to the second laying year is to be expected in a strain of Rhode Island Reds that lay large eggs. Just what would take place in a small-egg strain cannot be ascertained from these data, but earlier records (Hays, 1929) indicate about an 8 percent increase in a strain laying small eggs. There appears to be a slight decline in egg weight with age after the second laying year.

Atwood (1925) found much lower variability in egg weight in White Leghorns in the second laying year than in the first laying year. Our data are not in agreement with his observations, but the difference may be due to the period of observation and to the method of calculating the standard deviation. Atwood calculated the standard deviation on the individual egg basis, while we have calculated the standard deviation for March on the basis of the individual standard deviation in the month of March.

TABLE 4.—EFFECT OF AGE ON EGG WEIGHT AND VARIABILITY IN EGG WEIGHT.

Number of Birds	Mean Egg Weight and Standard Deviation in Egg Weight, Grams			
	First Laying Year	Second Laying Year	Third Laying Year	Fourth Laying Year
95	62.4 ± 1.94	65.0 ± 2.19		
24	61.2 ± 1.77	64.5 ± 2.18	63.8 ± 2.14	
23		62.4 ± 2.08	61.4 ± 1.87	
12		64.4 ± 1.77	63.6 ± 1.77	62.5 ± 1.64

Summary

Variability in egg weight has been studied over a six-year period. Normal variability has been determined by calendar months and for the entire first laying year. The strain of Rhode Island Reds used had been bred for high egg production for many years and may be considered a large-egg strain since the mean egg weight of the first laying year was 58.4 grams, or 24.7 ounces to the dozen.

From this study the following deductions seem to be justified:

(1) Maximum egg weight of the first laying year appeared in March, followed by a slight decline in April and a low summer level in May. In June the egg weight began to increase and increased consistently to September when the March level was again attained. The March and September egg weights were about 3 percent greater than the annual mean.

(2) Monthly variability in egg weight was greatest in November and December, when egg size was increasing at the most rapid rate, and lowest in May.

(3) The month of March is a good time to evaluate the flock for egg size, because egg size is then at a maximum and variability in egg size is at a low level.

(4) Inherited variability in egg weight has almost completely disappeared by March.

(5) Very early maturing pullets showed a high annual variability in egg weight; but there was no correlation between age at first egg and March variability in egg weight.

(6) Winter clutch size showed no correlation with annual or with March variability in egg weight.

(7) The presence or absence of winter pause had no effect on either annual or March variability in egg weight.

(8) The presence or absence of the broody instinct had no effect on annual or March variability in egg weight.

(9) No correlation was observed between persistency and annual variability in egg weight; but there was a slight negative correlation between persistency and March variability in egg weight.

(10) The first egg of a clutch generally weighs more than any other egg of the clutch; and the rate of decline in weight of the successive eggs of a clutch is least in intense laying birds.

(11) Variability in egg weight was greatest for the first egg of a clutch and declined with each succeeding egg.

(12) There was no correlation between mothers and daughters in March variability in egg weight.

(13) There was a small negative correlation between annual egg production and annual variability in egg weight.

(14) There was no significant correlation between body weight at first egg and annual egg weight.

(15) A slightly significant negative correlation was found between body weight at the end of the first laying year and annual egg weight.

(16) In a strain that lays large eggs, an increase of from 4 to 5 percent in egg weight may be expected between the first and the second laying years.

(17) There is some evidence of a slight decline in egg weight after the second laying year.

(18) These data furnished some evidence of inherited variability, particularly during the first part of the laying year.

References

Atwood, Horace. 1923. Certain correlations in the weight and number of eggs and the weight of fowls. W. Va. Agr. Expt. Sta. Bul. 182.

Atwood, Horace. 1925 The standard deviation in the weight of White Leghorn eggs. W. Va. Agr. Expt. Sta. Bul. 195.

Atwood, Horace, and C. E. Weakley, Jr. 1917. Certain characteristics of hen eggs. W. Va. Agr. Expt. Sta. Bul. 166.

Clark, T. B. 1940. The relation of production and egg weight to age in White Leghorn fowls. Poultry Sci. 19 (1):61-66.

Funk, E. M., and H. L. Kempster. 1934. Egg weight in the domestic fowl. Mo. Agr. Expt. Sta. Bul. 332.

Goodale, H. D., Ruby Sanborn and Donald White. 1920. Broodiness in domestic fowl. Mass. Agr. Expt. Sta. Bul. 211.

Hays, F. A. 1924. Inbreeding the Rhode Island Red with special reference to winter egg production. Amer. Nat. 58 (654):43-59.

Hays, F. A. 1927. The inheritance of persistency and its relation to fecundity. Proc. World's Poultry Cong. 92-95.

Hays, F. A. 1929. The inheritance of egg weight in the domestic fowl. Jour. Agr. Res. 38 (9):511-519.

Hays, F. A. 1930. Increase in egg weight during the pullet laying year. Poultry Sci. Assoc., Proc. of the Twenty-second Annual Meeting.

Hays, F. A. 1934. Time interval from first egg to standard egg weight in Rhode Island Red pullets. Mass. Agr. Expt. Sta. Bul. 313.

Hays, F. A. 1936. Winter pause in Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 329.

Hays, F. A. 1936a. Studies on the inheritance of persistency. Genetics 21:519-524.

Hays, F. A., and Ruby Sanborn. 1927. Intensity or rate of laying in relation to fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 11.

Hays, F. A., and Ruby Sanborn. 1927a. Net correlations of characters concerned in fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 12.

Hays, F. A., and Ruby Sanborn. 1932. Types of intensity in Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 286.

Hays, F. A., and Ruby Sanborn. 1934. Breeding for egg production. Mass. Agr. Expt. Sta. Bul. 307.

Jeffrey, F. P. 1938. The measurement of egg weight. Poultry Sci. 17 (3):179-186.

Jull, M. A. 1924. Egg weight in relation to production, I. Poultry Sci. 3 (3):77-88.

Jull, M. A. 1940. Poultry Breeding. John Wiley & Sons, New York, 328 pp.

Jull, M. A., and A. B. Godfrey. 1933. Mean annual egg weight in relation to mean weight of first ten eggs laid. Poultry Sci. 12 (5):310-312.

Knox, C. W., M. A. Jull, and J. P. Quinn. 1935. Correlation studies of egg production and possible genetic interpretations. Jour. Agr. Res. 50 (7):573-589.

Lerner, I. M., and L. W. Taylor. 1937. The measurements of sexual maturity and persistency. Poultry Sci. 16:419-421.

Lerner, I. M., and L. W. Taylor. 1939. A statistical study of winter pause in White Leghorn pullets. Jour. Agr. Res. 59 (3):199-210.

Marble, D. R. 1931. A statistical study of factors affecting egg weight in the domestic fowl. Poultry Sci. 10 (2):84-92.

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

AUG [illegible] 1944

Bulletin No. 412 February 1944

The Cabbage Maggot

By W. D. Whitcomb

The Cabbage Maggot is a destructive pest of cruciferous plants in Massachusetts, and successive crops can seldom be grown successfully without providing protection against it. The most satisfactory treatments to use on certain types of plants and for different degrees of infestation are recommended.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

RECOMMENDATIONS FOR CONTROL OF CABBAGE MAGGOT

1. Destroy all "stumps" and roots of cruciferous crops either by pulling or by plowing as soon as the crop is harvested. This applies especially to fall crops, which are the principal source of the flies in the spring.

2. Plant cabbage and other susceptible crops as far from a previous planting as practical. The flies migrate, but an infestation is delayed by rotation with non-susceptible crops.

3. On seedlings in the seedbed or cold frame from May 5 to 30, or from June 10 to 30, use one of the following treatments:
   a. Cover with 20 to 30 mesh cheesecloth.

   b. Apply corrosive sublimate solution 1-1920 (1 ounce in 15 gallons of water). Make TWO OR THREE applications 7 days apart, using 1 gallon on 40 to 50 feet of row. If the infestation is very heavy, use a 1-1280 solution (1 ounce in 10 gallons of water) in the same way.

4. On early transplants in the field, use one of the following treatments:
   a. When a heavy infestation is expected:
      Apply corrosive sublimate solution 1-1280 (1 ounce in 10 gallons of water) at the rate of ½ cupful per plant, making TWO applications at weekly intervals beginning when the first eggs are laid (May 5 to 10 at Waltham).
      OR: Apply calomel–talc dust (4 percent calomel) in a mound around the stem of the plant, using 1 teaspoonful per plant, before the first eggs are laid.

   b. When a moderate or light infestation is expected:
      Apply corrosive sublimate solution 1-1920 (1 ounce in 15 gallons of water) making TWO applications as in 4-a above.
      OR: Apply corrosive sublimate solution 1-1280 (1 ounce in 10 gallons of water), using ½ cupful per plant and making ONE application about 1 week after the first eggs are laid.
      OR: Apply calomel–talc dust (2 percent calomel) in a mound around the stem of the plant, using 1 teaspoonful per plant before the first eggs are laid.
      OR: Apply calomel–talc dust (4 percent calomel) directed at the base of the plant with a hand duster, making THREE applications at weekly intervals beginning when the first eggs are laid.

   c. On transplants without soil on roots, especially southern-grown plants, moisten roots and dust stems and roots with calomel–talc dust containing 50 percent calomel just before transplanting.

   d. In the home garden, apply a tar paper disc around the stem of each plant when the plants are transplanted.

5. Compare the cost of these treatments as shown in Table 13, page 24.

THE CABBAGE MAGGOT

W. D. Whitcomb, Research Professor of Entomology[1]

Although the cabbage maggot is native to Europe, it has been well known in North Amerca for about one hundred years and has become so well established in the northern part of this country that it is now recognized as one of the most common and injurious insect pests of the cruciferous vegetables. Cool, moist weather favors the development of the cabbage maggot and it is most destructive in the northern states and in Canada. Unpublished notes by Prof. Fred C. Sears, formerly of the Massachusetts State College and a member of several Grenfell expeditions, state that this insect is a very destructive pest of cruciferous crops in Labrador.

In Massachusetts the cabbage maggot is troublesome each year, and at Waltham during recent years 70 to 80 percent of the untreated early cabbage and cauliflower plants have been attacked regularly, with the infestation reaching 95 to 100 percent in favorable seasons (Figure 1).

DESCRIPTION AND LIFE HISTORY

The cabbage maggot fly, *Hylemya brassicae* Bouché, belongs to the family *Anthomyiidae.* The flies of this family are frequently seen around flowers, and somewhat resemble the common housefly. The maggots of most genera in this family feed in living or decayed vegetable matter but a few are parasites in living insects.

The cabbage maggot has four stages of development: egg, larva or maggot, puparium, and adult or fly (Figure 2). The most important characters are described briefly.

Egg

Glistening white, oval in shape, about 1/25 of an inch long and one-third as thick, with several longitudinal furrows on the surface (Figure 2-A). The eggs are laid singly but are often found in groups in cracks and crevices in the soil near the stem of the plants (Figure 3-A).

Larva

White, generally cylindrical but tapering to a relatively sharp point at the head. At the rear or blunt end there are several tubercles of which two pairs are large and more noticeable. Under favorable conditions the maggots become full grown in about three weeks and are about 1/3 inch long, although their size is dependent on the food supply and some are scarcely more than 1/10 inch long when fully grown (Figure 2-B).

---

[1] Acknowledgments are gratefully given to Harold A. Wilson, Foreman, formerly Technical Assistant; to William Garland, Technical Assistant; and to Wm. E. Tomlinson, Jr., Laboratory Assistant, who did much of the field work reported in this bulletin.

Puparium

Elongate-oval, rounded at both ends, with noticeable forked tubercles, about 1/4 inch long and dark brown in color. The puparia are usually found near the surface of the soil and within four or five inches from the root of the plant on which the larvae developed. During the summer the pupation period is ten to twenty days, but those larvae which pupate in the autumn live in the puparia through the winter (Figure 2-C).

Adult

A bristly black fly with gray markings, resembling the common house fly but smaller and quicker in its movements. At rest, the wings are held flat against the body. There are three dark longitudinal lines on the back of the thorax. The average length is about ¼ inch, and the abdomen of the male is much smaller than that of the female. During the oviposition period the female flies crawl and hop over the soil near the stems of the host plants (Figure 2-D).

SEASONAL HISTORY

There are normally three generations annually, with the majority of the flies appearing in May, July, and September and being active for about a month at each period. The average life cycle requires five to seven weeks, and this period is influenced a great deal by temperature and moisture. In Massachusetts the first generation, which attacks early cabbage and related crops, is by far the most destructive and abundant. The second generation is the least destructive, and although many maggots live on the stems of mid-season cabbage, cauliflower, and broccoli, the principal damage to garden crops by this generation occurs on radishes planted between June 10 and 30. The third generation maggots feed in turnips, late radishes, and especially in the stumps of cabbage and related crops which are left in the field in September and October. (See Table 3.)

Table 1. Relative Susceptibility of Host Plants to Attack by Cabbage Maggot. Waltham, Massachusetts.

CROP	PERCENT OF PLANTS INFESTED							
	1930	1931	1932	1934	1937*	1938*	1939*	Average
Cabbage**	33	75	96	86	95	77	87	78.4
Cauliflower	37	89	58				100	71.0
Broccoli	14	58					84	52.0
Brussels Sprouts	16	62					56	44.7
Radish	71			83	92	37	45	65.6
Turnip (Purple Top)	21							21.0
Kohlrabi							84	84.0
Chinese Cabbage							64	64.0
Collards							88	88.0

* Commercially injured = moderate or severe injury, or dead (omits slight or very slight infestation).

** Copenhagen Market or Golden Acre variety.

1930-1934 records refer to infested plants.

1937-1939 records refer to plants showing commercial injury.

HOST PLANTS

The cabbage maggot feeds on all members of the mustard family, *Cruciferae*. Metcalf and Flint (8) and Chittenden (3) report that it has been found feeding on celery and beets but this has not been observed in Massachusetts.

Among the common garden vegetables cabbage, cauliflower, and radish are frequently damaged extensively and seriously, while in some localities fall turnips have been severely attacked. When cabbage and cauliflower are grown in the same field, the cauliflower is usually damaged more severely. At Waltham, in 1939, Chinese cabbage, collards, and kohlrabi were infested about as heavily as cabbage but this is apparently unusual.

The extent of injury to different host plants which have been grown at Waltham is shown in Table 1.

Susceptibility of Cabbage Varieties

Cabbage varieties show some variation in susceptibility to injury by the cabbage maggot. Brittain (1) in Nova Scotia reported complete immunity for the large Red Drumhead variety, and Glasgow (5) in New York showed a definite resistance for the Danish Ballhead as compared to the Copenhagen Market variety.

During 1942 and 1943, at Waltham, thirteen varieties of cabbage were observed for susceptibility to injury, as shown in Table 2.

TABLE 2. SUSCEPTIBILITY OF CABBAGE VARIETIES TO INJURY BY THE CABBAGE MAGGOT. WALTHAM, MASSACHUSETTS, 1942-1943.

Variety	Seasonal[1] Maturity	Percent of Plants Commercially Injured		Percent of Salable[2] Heads		Percent of Unsalable[3] Heads	
		1942	1943	1942	1943	1942	1943
Early Jersey Wakefield	Early	17.3	13.3	62.7	95.6	37.3	4.2
Penn State Ballhead	Late	30.1	35.5	53.3	71.1	46.7	28.9
Glory of Enkhuizen	Intermediate	37.3	—	49.3	—	50.7	—
Allhead Early	Intermediate	38.7	68.9	74.7	66.7	25.3	33.3
Red Acre	Intermediate	41.3	46.7	52.0	68.9	48.0	31.1
Mammoth Red Rock	Late	48.0	44.4	41.3	62.3	58.7	37.7
Cornell Early Savoy	Early	49.3	48.9	60.3	61.4	39.7	38.6
Red Drumhead	Late	58.7	—	40.0	—	60.0	—
Premium Flat Dutch	Late	58.7	—	52.0	—	48.0	—
Golden Acre	Early	58.7	76.7	33.3	45.6	66.7	54.5
Marion Market	Early	60.0	—	33.3	—	66.7	—
Copenhagen Market	Early	77.3	—	13.3	—	86.7	—
Supercurled Savoy	Intermediate	74.7	—	22.7	—	77.3	—

[1] Classification of most varieties was taken from Morrison, Drewes and Coulter, Mich. Agr. Expt. Sta. Spec. Bul 249, 1934.

[2] Salable heads include those which were classified as Very Large, Large, and Medium at the time they were examined.

[3] Unsalable heads include those which were classified as Small, Very Small, Blind, or Dead at the time they were examined. Some of the Small heads might grow to salable size, but they were not salable when classified. The classification of injury and head size was made on different plants and there is, therefore, no direct correlation between the corresponding percentages.

No repellency or attractiveness to the flies was observed and eggs were laid in about equal numbers among these varieties. It, therefore, appeared that the degree of injury was dependent on the ability of the plant to withstand the feeding of the maggots.

On this basis the Early Jersey Wakefield variety was consistently resistant during the two years observed; Copenhagen Market, Supercurled Savoy, Marion Market, and Golden Acre were very susceptible; and all others were intermediate or inconsistent. In general it appears that fast-growing, more desirable market varieties are the most seriously injured, with Early Jersey Wakefield an outstanding exception, and that the slower growing varieties are more resistant.

INJURY

Injury to plants by the cabbage maggot is caused entirely by the feeding of the larva or maggot. When first hatched, the tiny maggot crawls down the main root and feeds on the hairy roots. As the larva grows, it may eat all of the hairy roots or it may eat channels into the main root.

On small seedlings and transplants, the feeding of one or two maggots may stunt the plant. The feeding of three or four maggots usually kills a small plant or stunts it beyond normal recovery.

Large plants in which one or two maggots have eaten channels or small cell-like cavities in the main stem usually show little or no effect from the injury. However, when several maggots attack a large plant, the hairy feeding roots are eaten off and the main roots become perforated with tunnels. The plant tissues around these tunnels decay and the lower root disintegrates (Figure 3-B). In severe infestations some maggots may tunnel upward in the stem and live as borers even burrowing into the petiole of the lower leaves.

Infested plants first show the effect of maggot injury by developing a pale gray color and a dull appearance. On warm, sunny days, and on windy days when transpiration is rapid, infested plants wilt and droop. Badly infested plants supporting five or six maggots are frequently killed, but slightly or moderately infested plants may wilt for several days and recover at night until the development of secondary roots enables the plant to outgrow the injury.

On radish, turnip and kohlrabi, the fleshy edible root is usually attacked and one maggot tunnel makes the vegetable unmarketable as first-class produce.

Relation of Maggot Injury to Development of Head In Cabbage

Most cruciferous crops, especially cabbage, have a remarkable ability to recover from root injury by the cabbage maggot in cool, damp weather and in moist soil. Even when the main root is severely damaged, secondary roots usually above the point of injury frequently develop rapidly. In cool, moist weather these secondary roots will support a plant one-third to one-half grown and enable it to recover. The growth of these secondary roots is well illustrated in Figure 3-C.

The recovery of infested plants in favorable seasons often enables growers who have applied ineffective treatments against cabbage maggot or none at all to harvest a reasonably profitable crop.

CONTROL

General Precautions

All cultural practices which reduce the number of cabbage maggots in an area where cruciferous crops are grown are important.

On early plantings one of the recommended control treatments should be carefully applied, and if two plantings of the same or related crops are made annually, the second crop should be planted at some distance from the field where the early crop was grown.

On late crops of cabbage and cauliflower, the cabbage maggot is seldom a destructive pest, but the third generation of this insect develops almost entirely in the roots of the late crops and becomes the source of flies for the following spring generation. On late crops of turnips and radishes, however, the third generation of the cabbage maggot may be very destructive and abundant. The stumps of cabbage, cauliflower, and broccoli may harbor large numbers of cabbage maggots, as shown in Table 3; and even though worthless, these stumps should be gathered and destroyed and the soil plowed just before the ground freezes.

TABLE 3. NUMBER OF CABBAGE MAGGOT PUPAE COLLECTED IN TEN 6 × 6 × 6 INCH SOIL SAMPLES AROUND OVERWINTERED HOST PLANTS. WALTHAM, MASSACHUSETTS, APRIL 18, 1941.

Host	Type of Planting	Number of Pupae Collected per Plant	
		Maximum	Average
Yellow Turnip	Small experimental plot	51	19.9
Broccoli stumps	Small experimental plot	14	4.9
Cabbage stumps	Large commercial field	11	1.9

Relation of Biology to Control

Any insecticide or repellent applied for combating this insect must be active when the flies are laying eggs or when the maggots are hatching and beginning to feed. Therefore, the application of control measures must be timed according to the biology and development of the insect. The treatments discussed in this bulletin should be begun at the time or just before the first eggs are laid and should give protection during the hatching period of the larvae; hence it is necessary to know the time when these activities occur for successful application of control measures. A knowledge of the seasonal biology of the cabbage maggot is particularly desirable since injury by this insect is seldom apparent until after the infestation has become established and the greater part of the damage to the plant has been done. Then the pest can be controlled only with great difficulty, if at all.

In Geneva, N. Y., Glasgow (5) determined that the first flies appeared about the time the Windsor cherries and the Reine Claude plums were in full bloom. At Waltham no records of the appearance of flies have been made. However, careful records show that the first eggs have been laid in the field during the twelve-day period April 29 to May 10, and that the first eggs have been found in the six-day period May 5-10 in ten of the thirteen years when observations were made.

TABLE 4. DATE ON WHICH THE FIRST EGGS OF THE CABBAGE MAGGOT WERE FOUND AT WALTHAM, MASS.

1931 — May 8	1935 — May 8	1940 — May 10
1932 — May 9	1936 — May 5	1941 — April 30
1933 — May 9	1937 — May 7	1942 — May 1
1934 — May 7	1938 — April 29	1943 — May 10
	1939 — May 10	

The records shown in Table 4 are remarkably uniform for a thirteen-year period, and seem to be a satisfactory index for timing control treatments in this locality.

If these dates are used for timing control treatments, the prevailing climatic conditions in any particular locality should be compared to those at Waltham. For example, observers in Bristol County (Massachusetts) have frequently found the first eggs about five days earlier, and in northern Worcester County (Massachusetts) seven to ten days later than they have been found at Waltham.

Methods Used in Classifying Injury and Development of Head in Cabbage and Cauliflower

In the experiments reported in this bulletin, records of maggot injury and of head development were taken from 1930 to 1934 by examining the head and roots of each plant about ten weeks after it was transplanted. By this method it was possible to determine the number of plants which were seriously injured or killed by the cabbage maggot, but an accurate determination of slight or moderate injury could not be made after the wounds had healed and the plant had largely recovered.

From 1935 to 1943 the plants were transplanted 18 inches apart in double rows 18 inches wide. Each application of insecticide or other treatment was made to two identical adjacent rows, one of which was used to record maggot injury and the other to furnish data on the development of the head. Early in June, about six weeks after transplanting and after the injury by the first generation of the cabbage maggot was nearly completed, the plants in one of each double row were pulled and the roots carefully examined for injury (See Figure 4). The injury was classified as:

> *Slight* — One or two maggots found, or evidence of feeding by not more than two maggots; plant generally showed very little effect from injury of this type.
>
> *Moderate* — Three or four maggots found, or evidence of feeding by not more than four maggots; plant smaller than normal but probably will recover and produce a small or medium-sized head.
>
> *Severe* — Five or more maggots found or feeding roots almost completely destroyed and main root stem badly injured; the plant will probably die although occasionally it will recover and produce a small and late-maturing head.
>
> *Dead* — Killed by maggot injury to the roots.

In the text of this bulletin and in the tables, the experimental plants are frequently referred to as *Commercially Injured*, which includes those suffering Moderate or Severe Injury and Dead Plants; and as *Commercially Uninjured*, which includes those suffering Slight Injury and those which are Free from Injury.

Early in July, about ten weeks after transplanting, the plants in the remaining row were examined and an average size of head for the planting and for the variety was determined, after which each head was classified in relation to the average as Very Large, Large, Medium, Small, Very Small, Dead, or Blind. Blind plants, in which no head developed, were usually caused by injury to the central bud by cutworms, but occasionally resulted from plant deformities or mechanical injury. In this bulletin the Very Large, Large, and Medium heads are classified as *Salable* or *Marketable*; and the Small, Very Small, Dead, and Blind heads are classified as *Unsalable* or *Unmarketable*. Some of the Small heads might grow to salable size before harvest was completed, but they were not of salable size when classified.

Although there is a general correlation between the amount of injury by cabbage maggot and the number of marketable heads, there is no direct relation between the percentages presented in the tables because the records were made on different rows of plants, and the head records were taken about four weeks later than the injury records.

Natural Infestation in Experimental Field at Waltham

Since 1930 when early cabbage was first grown in large numbers, there has been a heavy infestation of cabbage maggot on the untreated plants in the experimental planting. In the fourteen years when records were made, the number of cabbage plants commercially injured has been less than 75 percent in only three years; the infestation was 95 percent or higher in 1932, 1935, and 1937; and in the other eight years it ranged between 75 and 88 percent (Table 5). The infestation was 10 to 15 percent greater on cauliflower than on cabbage in those years when both crops were examined. Such infestations have provided good conditions for experimental tests of preventive treatments.

Table 5. Natural Infestation on Cabbage in Experimental Field at Waltham, Massachusetts. Golden Acre Variety.

Untreated Plants Commercially Injured

Year	Percent	Year	Percent	Year	Percent
1930	33	1935	98	1940	68
1931	75	1936	88	1941	86
1932	96	1937	95	1942	79
1933	57	1938	77	1943	77
1934	86	1939	87		
				Average	78.7

Artificial control treatments are classified as follows: Seedbed treatment, Pre-transplanting treatment, and Field treatment.

Seedbed Treatment

In Massachusetts the earliest cruciferous crops are usually started under glass and transplanted to the field before the first cabbage maggot infestation occurs and, therefore, they do not need protection in the seedbed. However, many cabbage, cauliflower, and related plants are growing in seedbeds between May 5 and May 30 or June 10 and July 1 when the flies are laying eggs and the young plants are exposed to infestation. This is especially true of summer and fall plantings which are seeded between May 15 and June 15.

Corrosive sublimate solution is the most satisfactory material for seedbed protection against the cabbage maggot as well as such diseases as club root, blackleg, and damping-off. Clayton (4) recommends a 1-2000 solution (1 ounce of corrosive sublimate dissolved in 15 gallons of water*) to control the common diseases. Glasgow (5) recommends a 1-1280 dilution (1 ounce in 10 gallons of water) to combat the cabbage maggot but shows that where the treatment was carefully applied a 1-1920 dilution was practically as effective as the stronger concentration. In fact, the actual increase in control from the stronger solution was 1 percent or less. He also shows that the 1-1280 dilution was harmful to cabbage and cauliflower seedlings growing in dry, sandy soil.

No definite experiments to control cabbage maggot in the seedbed have been made at Waltham, but in view of the above reports from New York as well as the results of dosage experiments shown in Table 12 the recommendations for seedbed treatment are:

Apply corrosive sublimate solution, prepared by dissolving 1 ounce of corrosive sublimate in 15 gallons of water (1-1920), using 1 gallon of the solution on about 40 feet of row or 20 square feet of bed. Applications should be made first as soon as the flies appear or at the beginning of one of the fly periods and repeated three or four times at weekly intervals.

Where corrosive sublimate is not available or its use is undesirable for any reason, a cheesecloth screen which tightly covers the coldframe or the seedbed will effectively protect the seedlings during the critical fly periods.

In New York (6) a calomel-gum suspension, which is described on page 18, is recommended, but this treatment has not been used on the seedbed at Waltham.

Pre-Transplanting Treatments

In some sections, particularly on Long Island, N. Y., seedlings are protected from cabbage maggot by coating the stem and upper part of the root with calomel, either as a powder or as a liquid suspension (2), just before they are transplanted to the field.

Experiments with this method were made at Waltham from 1935 to 1940 as shown in Table 6. Dusts containing equal parts of powdered calomel and clay or talc and 1 part of calomel with 3 parts of clay or talc were the most satisfactory and consistently provided 75 to 85 percent commercial protection and produced 70 to 80 percent salable heads. The best control (about 95 percent) was obtained from pure powdered calomel alone and from a mixture containing 3 parts of calomel and 1 part of diluent, but these treatments occasionally injured the roots and checked the growth of the plants. Dusts containing less than 20 percent calomel were relatively ineffective, especially against heavy infestations, although they showed 50 to 60 percent less injury than was suffered by untreated plants.

---

*Actually 1 ounce in 15 gallons is a dilution of 1 to 1920.

TABLE 6. CONTROL OF CABBAGE MAGGOT AND EFFECT ON GROWTH OF HEAD OBTAINED FROM APPLICATIONS OF CALOMEL INSECTICIDES TO STEM AND ROOTS OF CABBAGE AT TRANSPLANTING. WALTHAM, MASSACHUSETTS.

Percent of Calomel in Powder	Carrier	1935	1936	1937	1938	1939	1940	Average
Percent of Commercially Uninjured Plants								
100	None		88.0	92.0	89.33	97.33	100.0	93.33
75	Talc (fibrous)				98.0	97.98		97.99
50	Gypsum	79.0				97.99		88.50
50	Clay (Bancroft)		60.0	64.0				62.0
50	Talc (fibrous)				90.67	93.33	78.7	87.57
50	Talc (amorphous)						88.0	88.00
25	Clay (Bancroft)		42.0	80.0				61.00
25	Talc (fibrous)				86.67	90.00		88.33
25	Talc (fibrous)						68.0	68.0
25	Talc (amorphous)						77.3	77.3
20	Gypsum	73.0						73.0
10	Clay (Bancroft)			54.0				54.0
10	Talc (fibrous)				60.67	82.43		71.55
8	Gypsum	56.0						56.0
5	Talc (fibrous)				64.0	61.07		62.53
4	Gypsum	40.0						40.0
Check (Standard Treatment*)		100.0	88.0	98.0	100.0	99.33	100.0	97.56
Check (Untreated)		40.0	12.0	5.0	22.67	12.66	32.0	14.72
Percent of Large and Medium Heads								
100	None		82.0	86.0	86.67	65.96	57.3	75.59
75	Talc (fibrous)				78.67	71.98		75.33
50	Gypsum	63.83				70.65		67.24
50	Clay (Bancroft)		40.0	94.0				67.00
50	Talc (fibrous)				82.67	57.29	68.0	69.32
50	Talc (amorphous)						78.6	78.6
25	Clay (Bancroft)		50.0	92.0				71.00
25	Talc (fibrous)				90.00	79.95		84.98
25	Talc (fibrous)						71.90	71.90
25	Talc (amorphous)						81.30	81.30
20	Gypsum	56.99						56.99
10	Clay (Bancroft)			76.0				76.0
10	Talc (fibrous)				76.67	80.60		78.63
8	Gypsum	19.0						19.0
5	Talc (fibrous)				72.67	78.59		75.63
4	Gypsum	3.0						3.0
Check (Standard Treatment*)		87.75	70.0	82.0	83.33	93.25	72.0	89.72
Check (Untreated)		5.34	13.0	1.0	62.0	27.33	52.87	26.92

*Corrosive Sublimate 1-1280, two applications at weekly intervals beginning when the first eggs are laid.

The powder is applied by dusting the stem and upper roots, using a can that has a perforated cover, such as a flour shaker, or by swabbing and brushing it on by hand. It is essential to place a good coating on the stem at about the soil level and the amount of powder which naturally sticks to the stem is a satisfactory dosage. One man can easily treat the plants as rapidly as three or four men can set them by hand in the field. An excess of powder on the roots should be avoided to prevent possible injury, especially in dry soil. Plants grown in flats and cut out with soil blocks are difficult to treat by this method. In order to avoid excess soil on the roots, plants growing in coldframes should not be watered less than twenty-four hours before they are lifted for pre-transplanting treatment with calomel-clay dust.

Pre-transplanting treatment may also be applied by dipping the stem and roots in a calomel-water suspension (2) prepared by adding 8 ounces of the chemical to 10 gallons of water. At Waltham this treatment gave only 62 percent protection in 1936. Calomel suspensions were also prepared by adding various adhesive mixtures such as clay, laundry starch, gum arabic, locust bean gum, water soluble wax, and liquid rubber. The suspensions with clay and starch were the most satisfactory and gave good protection. However, they matted and stuck the roots together so persistently that the roots were burned slightly and the plants were stunted during the early stages of growth in the field.

When pre-transplanting treatments are applied, the maggots occasionally attack the root stem near the surface of the soil and above the portion of the stem which was treated. These stems are frequently badly scarred by channels and small cavities but little or no injury to the growth or development of the plant has resulted from this type of infestation.

Pre-transplanting treatments are limited in use. They are recommended especially on southern-grown plants and others which are transplanted with little or no soil on the roots and are set out by hand. Dust containing equal parts of calomel and talc or clay has been the most satisfactory material.

Field Treatments

The application of protective treatments after the plants are growing in the field is the most common method of control. These treatments may be roughly divided into three types: repellents, toxic dusts, and toxic liquid drenches.

REPELLENTS

Tar Paper Discs

One of the first recommended treatments for combating the cabbage maggot was to place a disc cut from tar paper around the stem of each plant at the surface of the soil. These discs were usually about three inches in diameter, hexagonal in shape, with a slit leading to the center where several flaps permitted the disc to fit tightly around the stem. When the discs fitted tightly and the soil was smoothed so that they lay flat on the soil, they prevented the flies from laying eggs near the plant and the odor of the tar paper repelled them.

At Waltham in 1933 these discs provided 76 percent commercial protection in a field where 57.33 percent of the untreated cabbage plants were commercially injured. (Table 7). In 1943, when the supply of calomel and corrosive sublimate for agricultural use was limited by war needs, tar paper discs were again used.

In these trials the soil was carefully smoothed and the discs were laid flat and evenly on the soil. Where there was 77 percent injury to the untreated plants, none of those protected with tar paper discs was commercially injured. Eggs were observed on the soil near the discs and 7 percent of the plants were lightly infested but showed no measurable damage to the growth of the plants. Several thousand discs were used by commercial growers with generally satisfactory results, although there was some difficulty in getting the discs laid carefully by inexperienced help.

The discs are considered an excellent substitute for preferred mercury treatments for the commercial grower and are highly recommended to all home gardeners. In 1943 a commercial supply of tar paper discs was available at a cost of 2 to 3 cents each depending on the number purchased.

TABLE 7. MULCH PAPER AND TAR PAPER DISCS AS REPELLENTS FOR THE CABBAGE MAGGOT. WALTHAM, MASSACHUSETTS.

Materials	Crop	Percent of Plants Commercially Uninjured				
		1930	1931	1933	1943	Average
Mulch Paper	Cabbage	92.0	70.0			81.0
	Cauliflower	78.0	36.0			57.0
	Broccoli	94.0	51.0			72.5
	Brussels Sprouts	84.0	44.0			64.0
	Radish	23.0				23.0
	Turnip	88.0				88.0
Tar Paper Discs	Cabbage			76.0	100.0	88.0
Check (Standard Treatment*)	Cabbage	96.0	100.0**	100.0	100.0	99.0
	Cauliflower	92.0	100.0**	—		96.0
Check (Untreated)	Cabbage	67.0	25.0	42.67	23.3	39.49
	Cauliflower	63.0	11.0			37.0
	Broccoli	86.0	42.0			64.0
	Brussels Sprouts	84.0	38.3			62.15
	Radish	29.0				29.0
	Turnip	79.0				79.0

*Corrosive Sublimate 1-1280, two applications at weekly intervals beginning when the first eggs are laid.

**In 1931 cabbage and cauliflower received four applications of Corrosive Sublimate.

Mulch Paper

About 1930 mulch paper prepared by treating paper with various asphalt mixtures created considerable interest as a means of stimulating plant growth by conserving moisture and providing more uniform soil temperatures. The paper was applied either by laying a strip about 12 inches wide on each side of the row usually after the plants were set, with the plants growing in a strip of exposed soil about 1 inch wide in the center, or by laying strips of paper about 36 inches wide and setting the plants at regular intervals through slits cut in the paper, thus providing a solid coating of paper over the field. The mulch paper was held in place with wire staples.

Experiments with wide strips of mulch paper as a repellent for cabbage maggot were made at Waltham in 1930 and 1931; but the results, as shown in Table 7, were generally unsatisfactory, especially in 1931 when a heavy infestation developed on the untreated plants. Poor control resulted when the paper curled at the edges two or three weeks after it had been laid, thus exposing the plants to the flies and providing a sheltered location in which they could lay eggs. When radish seed was sown with a double strip of mulch paper on each side of the seed row, a greater infestation occurred than where no treatment was applied.

Mulch paper caused a definite stimulation of plant growth in cabbage and cauliflower as shown by the weights of a few plants in Table 8.

Mulch paper as applied in these trials did not provide adequate and consistent protection against injury by the cabbage maggot nor was the gain in plant growth sufficient to offset the labor and expense of applying paper on these crops. If mulch paper is used, one of the chemical treatments described later should be used with it to provide protection against the cabbage maggot.

TABLE 8. STIMULATION OF CABBAGE AND CAULIFLOWER BY MULCH PAPER. WALTHAM, MASSACHUSETTS. 1930.

	Number of Plants	Weight of Plants			Gain in Weight Percent
		Maximum	Minimum	Average	
Cabbage					
Mulch Paper	10	5 lb. 10 oz.	4 lb. 4 oz.	4 lb. 13 oz.	32
None	10	4 lb. 4 oz.	2 lb. 2 oz.	3 lb. 5 oz.	—
Cauliflower					
Mulch Paper	10	4 lb.	2 lb.	2 lb. 15 oz.	17
None	10	3 lb. 8 oz.	1 lb. 8 oz.	2 lb. 7 oz.	—

INSECTICIDAL DUSTS

Naphthalene

Resublimed naphthalene, known to the trade as commercial naphthalene flakes, repels cabbage maggot flies and kills many eggs and newly hatched maggots which come in contact with it. In 1931 with a natural infestation of 75 to 90 percent, four applications broadcast at the rate of 3 pounds per 100 plants between May 7 and May 29 gave only moderate protection (Table 9). In 1934, however, three applications between May 7 and 21, at the same rate but with more care in applying the crystals close to the stem of the plant, gave 84 percent protection and produced the largest number of large and medium heads in the experiment.

The naphthalene flakes were applied by hand at the rate of approximately a large handful to each three plants, but broadcasting over the entire field would be effective. Some of the material should be on the soil throughout the oviposition period of the flies. On early crops this period usually extends through the month of May. The number of applications needed depends on the temperature, since the rate of evaporation increases with the temperature and the crystals must be replaced more frequently in warm weather. Observations show that when the temperature at the surface of the soil is 75° F. or higher, the naphthalene flakes from a normal application vaporize and lose their repellency in about three days.

For the home garden this treatment seems practical, but in commercial plantings the greater number of applications required makes it less desirable than corrosive sublimate or calomel. However, if mercury compounds are not available, or their cost becomes excessive, naphthalene might be used as a substitute.

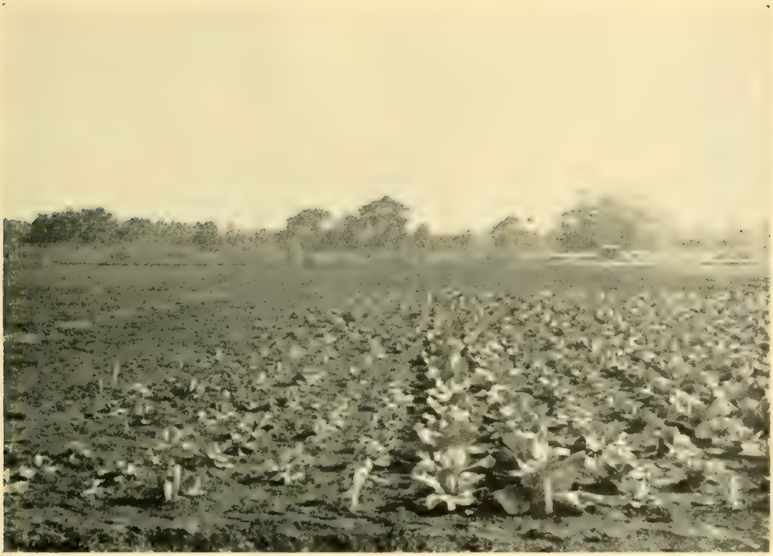


Figure 1. An Experimental Field of Cabbage Grown for Studying Methods of Controlling the Cabbage Maggot.

Right Center: Two rows of healthy plants which were treated with corrosive sublimate solution.

Left: Six rows of severely injured plants which received no treatment or ineffective treatments.

Photo by R. E. Young.

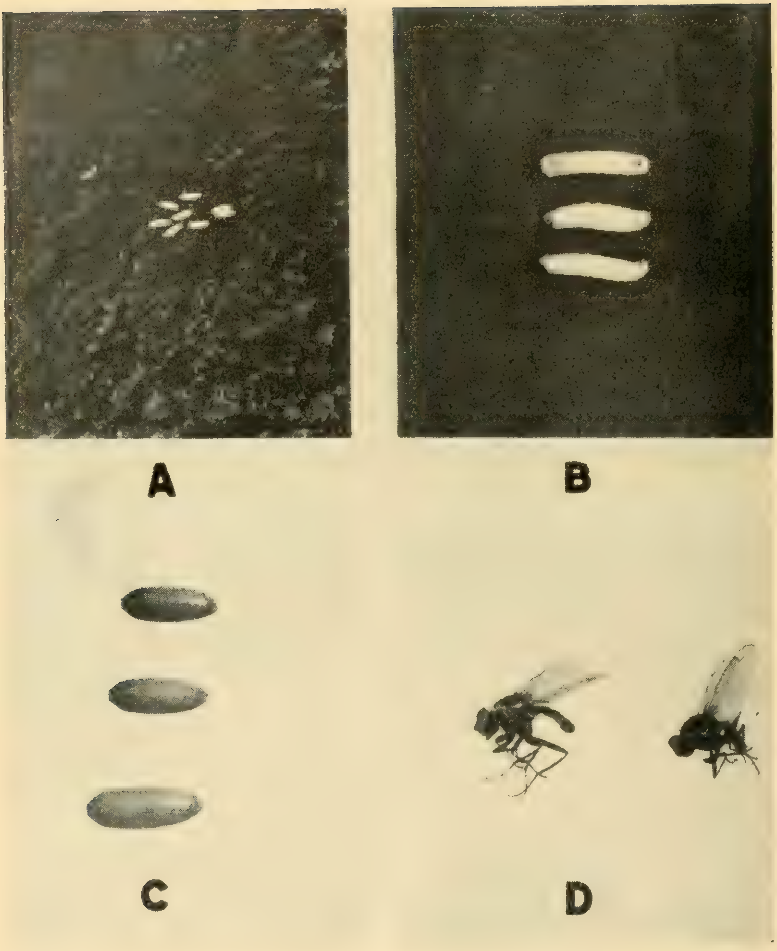


Figure 2. **Cabbage Maggot -- Life Stages**
Enlarged about twice.

A. Eggs
C. Puparia

B. Larvae or maggots
D. Adult or flies
Photo by R. L. Coffin.

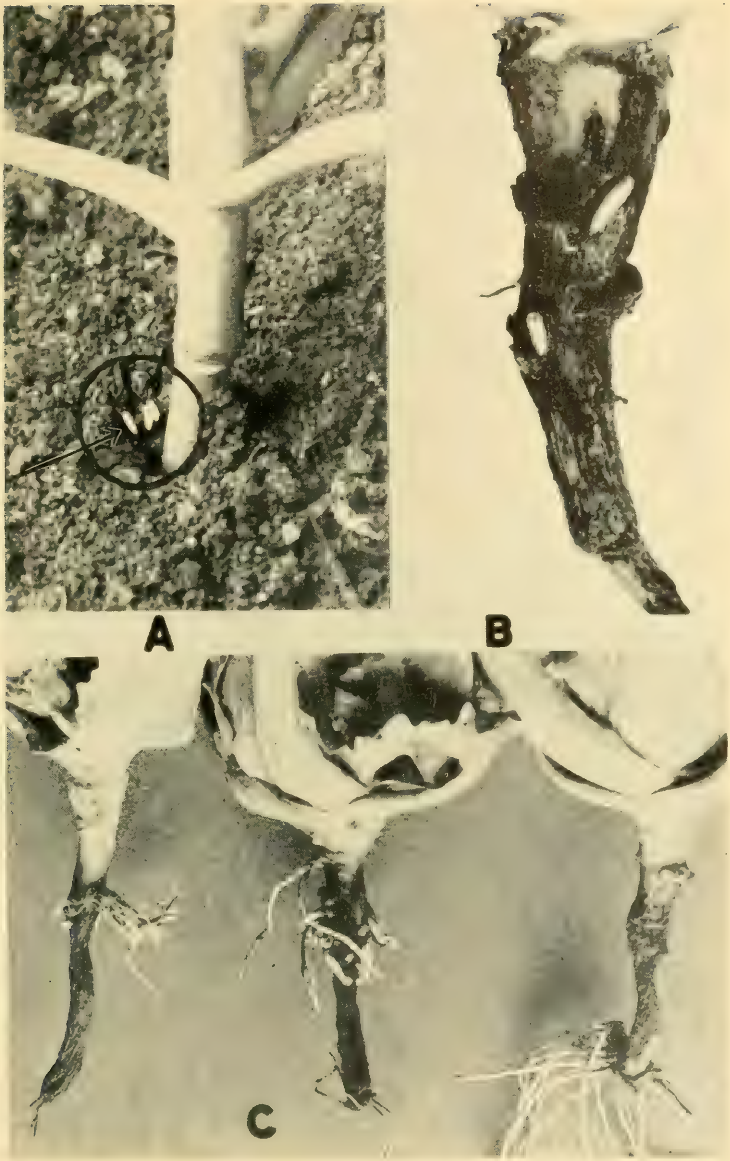


Figure 3. Cabbage Maggot Eggs and Injury.

A. Eggs in natural position near stem of plant (about natural size).

B. Severe injury to root of cabbage showing full-grown maggots in channels eaten in root stem.

C. Secondary roots grown on severely injured cabbage root stem. Such secondary roots frequently enable infested cabbage plants to recover and produce small but marketable heads.

Photo by R. L. Coffin.

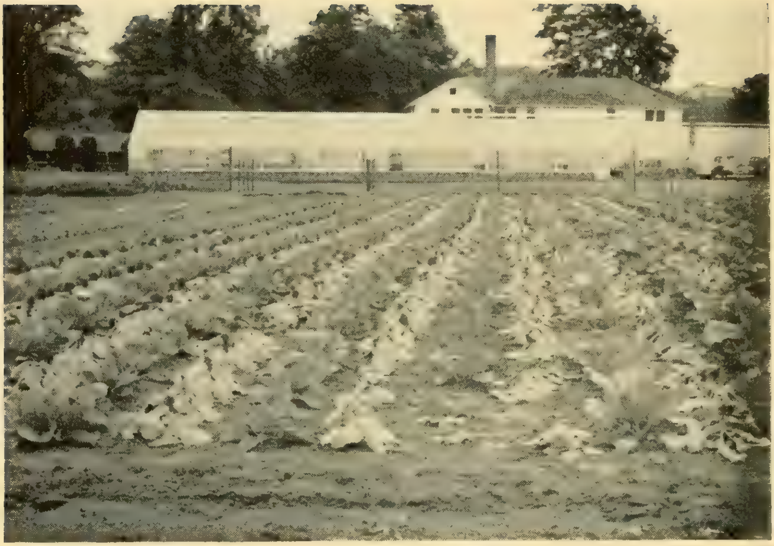


Figure 4. Experimental Cabbage Field at Waltham on June 1, 1942, showing alternate rows of cabbage plants pulled for examination of maggot injury to the roots, as described on page 8. The plants in the rows not pulled received the same treatment as those in the rows of pulled plants on their right, and were grown to maturity for data on head development.

Photo by W. E. Tomlinson, Jr.

Table 9. Effectiveness of Dust Applications for Control of Cabbage Maggot. Waltham, Massachusetts.

Material, Percent of Toxic Agent, and Carrier	Year	Applications		Crop	Percent of Plants Commercially Uninjured	Percent of Large and Medium Heads
		Number	Method			
Naphthalene Flakes[1] Naphthalene 100% No carrier	1931	4	Broadcast	Cabbage	60.0	—
	1931	4	Broadcast	Cauliflower	57.8	—
	1934	3	Broadcast	Cabbage	84.0	84.0
Cube Dust[2] Rotenone .5% Clay	1932	4	Duster	Cabbage	86.0	54.0
	1932	4	Duster	Cauliflower	56.0	16.0*
	1933	3	Duster, 1 side only	Cabbage	42.0	30.0
	1933	3	Duster, 2 sides	Cabbage	58.0	18.0
Derris Dust[3] Rotenone .55% Clay	1933	3	Duster, 1 side only	Cabbage	78.0	36.0
	1933	3	Duster, 2 sides	Cabbage	86.0	60.0
Calomel Dust[2] Calomel 2% Colloidal Clay	1932	4	Duster	Cabbage	100.0	78.0
	1932	4	Duster	Cauliflower	74.0	28.0*
	1933	3	Duster, 1 side only	Cabbage	96.0	52.0
	1933	3	Duster, 2 sides	Cabbage	98.0	76.0
Calomel Dust[4] Calomel 4% Lime	1932	4	Duster	Cabbage	100.0	74.0
	1932	4	Duster	Cauliflower	70.0	40.0*
	1933	3	Duster, 1 side only	Cabbage	98.0	72.0
	1933	3	Duster, 2 sides	Cabbage	98.0	84.0
	1933	4	Duster, 1 side only	Cabbage	98.0	60.0
	1933	4	Duster, 2 sides	Cabbage	100.0	54.0
Calomel Dust **(home mixed)**						
Calomel 2% Talc	1942	2	Duster	Cabbage	54.4	72.2
	1942	1	Mound method	Cabbage	92.2	77.8
	1943	1	Mound method	Cabbage	85.6	80.0
Calomel 4% Lime	1934	3	Duster	Cabbage	72.0	76.0
	1935	2	Duster	Cabbage	76.0	42.0
Calomel 4% Talc	1940	2	Duster	Cabbage	97.3	89.3
	1942	2	Duster	Cabbage	93.3	74.4
	1941	1	Mound method	Cabbage	100.0	75.8
	1942	1	Mound method	Cabbage	97.7	80.7
	1943	1	Mound method	Cabbage	100.0	88.9

[1] Naphthalene is composed of coarse flaky crystals and is not actually a dust.
[2] Supplied by Ansbacher Siegel Corp.
[3] Supplied by Bowker Chemical Co.
[4] Supplied by Apothecaries Hall Co.
*Poor heading of cauliflower due to factors other than maggot injury.

Rotenone

Rotenone-bearing dusts are not considered to be satisfactory for controlling the cabbage maggot. Rotenone kills the adults and newly hatched maggots but it loses its effectiveness in three or four days after application. In these experiments a cube dust containing 0.5 percent rotenone was used in 1932 and 1933, and a derris dust containing .55 percent rotenone was used in 1933. The cube dust in four weekly applications in 1932 gave good protection to cabbage but poor protection to cauliflower. In 1933 the derris dust was moderately effective in protecting against a light infestation (57 percent) when applied from two sides (Table 9), while the cube dust was unsatisfactory in three applications applied either from one side or from two sides. Although the newer derris and cube dusts containing .75 to 1.0 percent rotenone will undoubtedly give better protection than was obtained in the 1932 and 1933 experiments, it is not believed that rotenone will be as effective as mercury compounds for controlling the cabbage maggot.

In 1938 a derris dust containing .6 percent rotenone was applied weekly to six different plantings of radishes and no protection resulted from the treatment. In fact, the commercial injury was 1.67 percent greater on the treated than on the untreated radishes.

Calomel

Calomel dusts have been recommended and used for combating the cabbage maggot since about 1930, but growers have generally obtained variable results because of the difficulty in applying sufficient material around the stem of the plant under practical field conditions. In the experiments at Waltham, calomel dusts have given satisfactory control when applied by the duster method if accurately timed, and excellent control when applied by the mound method. Only powdered calomel is suitable for making calomel dust, and granulated calomel should not be used.

Dust containing 4 percent calomel is standard for cabbage maggot control. When used by the duster method, the 4 percent dust was definitely superior, but when applied by the mound method, a 2 percent calomel dust was also satisfactory.

Duster Method of Application. — Preliminary trials indicated that a plunger type hand duster was more desirable than a rotary fan type hand duster for use on cabbage, and this type was, therefore, used in most of the experiments at Waltham (Table 9). The dust discharged by one full stroke of the plunger was applied to the soil around the stem of each plant. In several of the tests the dust was applied from two sides of the plant; but, although the double application was slightly more effective than the single application, the difference was so small that the additional cost for labor and material was not warranted.

All applications were made at weekly intervals beginning when the first eggs were found. As shown in Table 10, one or more applications at this time were effective when a light infestation developed on untreated plants. In seasons when a heavy infestation developed, an application one week after the first eggs were found was the most effective of the single applications, but one application alone at any of the periods did not give satisfactory protection. Applications at both the first and second periods were the most effective, although this is not borne out by the figures in Table 10. The writer recommends from experience three applications during the first three periods. It is obvious from Table 10 that applications beginning in the third or fourth period, that is, two or three weeks after the first eggs are laid, do not give satisfactory protection.

TABLE 10. RELATION OF TIME AND NUMBER OF APPLICATIONS OF 4 PERCENT CALOMEL DUST BY THE DUSTER METHOD FOR CONTROL OF THE CABBAGE MAGGOT. WALTHAM, MASSACHUSETTS.

Number of Applications and Period When Applied*	Percent of Plants Commercially Injured						
	Light Infestation			Heavy Infestation			
	1933	1940	Average	1934	1935	1942	Average
One application							
1st		4.0	4.0	56	62		59
2d		7.0	7.0	48	44		46
3d				90	70		80
4th				80	86		83
Two applications							
1st and 2d		3.0	3.0	18	24	7	16.3
1st and 3d				30	34		32
1st and 4th				60	30		45
2d and 3d				44	46		45
2d and 4th				60			60
3d and 4th				68	82		75
Three applications							
1st, 2d, and 3d	2.0		2.0	28			28
1st, 2d, and 4th				28			28
2d, 3d, and 4th				86			86
Four applications							
1st, 2d, 3d, and 4th	2.0		2.0	28			28
None (Check)	57.0	68.0	62.5	86	99	88	91

Period when applied:
1st — On day when eggs were first found
2d — 1 week after first application
3d — 2 weeks after first application
4th — 3 weeks after first application

Mound Method of Application. — Since 1941 calomel dust has been applied in the experimental field at Waltham by placing a mound of the dust, equal to the amount held in a teaspoon, around the stem of each plant soon after transplanting or just before the active period of the flies. As shown in Tables 9 and 12, this treatment has consistently given excellent control, being completely effective in some experiments, and in many respects it has been the most satisfactory method used.

The mound method was first suggested to the writer by Neely Turner of the Connecticut Agricultural Experiment Station. At Waltham, a teaspoon has been used to dip the dust from a bucket and place it around the stem of the plant, but with a little care the dust can be "squeezed" from the hand to make a satisfactory application. This method requires considerable hand labor and no satisfactory equipment for mechanical application has been discovered. However, one application is sufficient and the labor for applying is no greater than that required for other effective methods of hand application. Calomel is an internal poison and when applied by hand reasonable precautions should be observed.

Dusts containing 4 percent and 2 percent calomel combined with talc or clay have both been used successfully and the concentration is discussed on page 22. If carefully applied, 100 pounds of dust will treat about 1 acre of plants.

LIQUID DRENCHES

Calomel–Gum Suspension

Calomel–gum suspension applied at the rate of ½ cupful per plant in the field, or 1 gallon to 40 to 50 feet of row or 20 square feet in the seedbed, has been recommended (6, 2).

At Waltham, in 1940, this material gave perfect protection (100 percent commercially uninjured) from the cabbage maggot on Golden Acre cabbage in the field when applied only when the first eggs were found, or at both the first and second application periods (Table 11, footnote). In this experiment, 68 percent of the untreated plants were commercially injured, which is considered a light or moderate infestation for this area.

Calomel–gum suspension is prepared in two operations. First, dissolve 4 ounces of gum arabic in 1 quart of boiling water (powdered gum arabic dissolves more easily than the granular form). Then, grind 4 ounces of calomel with about ½ pint of the gum arabic water solution in a mortar or round bottom bowl with a pestle or the back of a spoon. When a thick uniform paste is formed, add the remainder of the gum arabic solution and stir thoroughly. Ordinarily, each quart of this mixture is diluted to make 10 gallons of liquid for application, but if the infestation is light 1 quart of this mixture can be diluted to make 40 gallons.

Glasgow (6) states that in New York calomel–gum mixtures are prepared and handled by the trade, but no commercial sources of calomel–gum arabic are known in Massachusetts.

In spite of its excellent protection, the complicated method of home preparation makes this treatment impractical for many growers and it is recommended only if other materials are unavailable or other treatments have been found unsatisfactory.

Corrosive Sublimate Solution

For about 20 years, applications of corrosive sublimate solution have been the standard treatment for the control of the cabbage maggot, and the use of this solution has been widely recommended throughout the area where this pest is destructive (7).

Corrosive sublimate, also known as bichloride of mercury and mercuric bichloride, is prepared in the form of a powder, granular crystals, or pressed tablets. The powder and crystals are usually sold by the pound or fraction thereof, and the tablets in packages of 25, 50, or 100, each tablet usually weighing 7.3 grains. Corrosive sublimate is white but, in the tablet form especially, it is frequently colored blue to emphasize that it is poisonous and should be handled accordingly.

Corrosive sublimate corrodes metals and should be stored only in wood, glass, or porcelain containers. Likewise, whenever possible, the solution should be made in non-metallic containers. It should never be allowed to stand in contact with metal. The use of this solution in metal pumps and pipes is not advised, but if it is so used the metal equipment should be *thoroughly* flushed with clean water *immediately* afterwards.

Preparation of the Solution. — Corrosive sublimate solution is prepared by dissolving corrosive sublimate powder, crystals, or tablets in water. The chemical dissolves more quickly in hot water, and dissolving it in a small amount of hot water before diluting for application is often desirable. Because its solubility is limited, each ounce of the chemical should be dissolved in 1 pint or more of water. Otherwise, a saturated solution is formed and a part of the corrosive sublimate does not dissolve.

Dilution. — The standard dilution of corrosive sublimate in water for combating the cabbage maggot is 1-1280 or 1 ounce in 10 gallons. However, as noted in the discussion of seedbed treatment, this chemical has been used at dilutions ranging from 1-1000 to 1-2500 with generally good results, and the 1-1280 dilution was recommended because it was consistently effective under average conditions rather than because it was the minimum effective dilution. Furthermore, a 1-1920 dilution has frequently been used effectively on cauliflower to avoid injury from the stronger solution.

In experiments at Waltham in 1942 and 1943, a 1-1920 dilution gave very good protection on cabbage when carefully applied, and there was no significant difference in the effectivness of the 1-1920 dilution and the 1-1280 dilution. These results are shown in Table 12, and they are discussed under "Reduced Dosages."

From these results, as well as from personal observations, it is concluded that a 1-1920 dilution can be used effectively under favorable conditions and it is recommended when the chemical is scarce and the solution can be applied carefully.

In home gardens or where only a few plants are treated, corrosive sublimate solution may be prepared by dissolving the tablets. The usual corrosive sublimate tablet prepared for medicinal use weighs 7.3 grains and when dissolved in 1 pint of water makes a 1-1000 solution. Six tablets dissolved in 1 gallon of water makes approximately a 1-1300 solution, which is satisfactory to use for combating the cabbage maggot.

Method of Application. — Sufficient solution should be applied around the roots of each plant to thoroughly wet the soil at least 1 inch deep. Approximately 4 ounces or ½ cupful is an average application, and this amount was used in all of the experiments at Waltham.

On small plantings and on large plantings when sufficient labor is available, the solution can be applied by dipping it from a pail (Figure 5-A). A suitable dipper is easily made by attaching a wire handle to a glass jar holding ½ cupful. Knapsack sprayers with the nozzle removed and the flow of liquid regulated by the spring shut-off on the rod handle, and an ordinary watering pot from which the sprinkler head has been removed, have both been used. A few large growers have used a power spray machine operated at low pressure, but this is not recommended. Barrels or tanks mounted on low wagons with the solution flowing by gravity through one or more short lengths of hose which the operator squeezes by hand to regulate the flow have been used successfully, and at least one large cabbage grower adapted this idea to a tractor-drawn mechanical transplanter from which operators riding close to the ground treated two rows of plants at a time.

In much of the experimental work at Waltham, an applicator designed and made for treating cabbage plants was used. This apparatus, which is shown in

Figure 5-B, holds about 2 gallons of liquid and is operated by a spring shut-off valve connected to a ½-inch discharge pipe. The outlet of the discharge pipe must be turned upward slightly so that the liquid in the pipe will not run out when the valve is closed. The proper amount of liquid for treating each plant is discharged by quickly raising the valve rod with the fingers while holding the applicator by the bail. Comparative tests indicate that the solution can be applied effectively in about one-third less time than with a bucket and dipper.

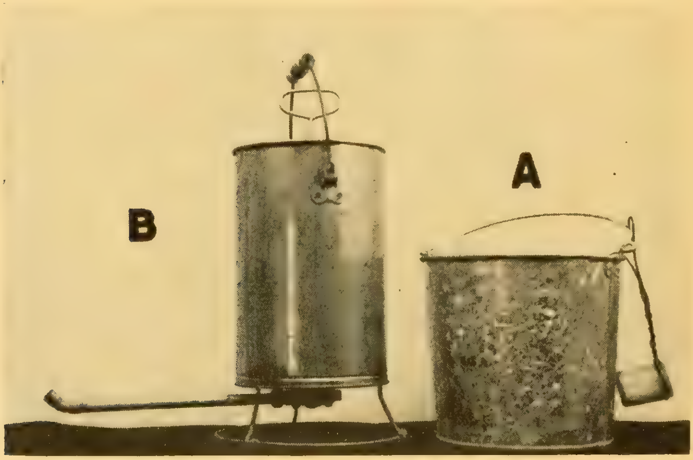


Figure 5. Equipment for Applying Corrosive Sublimate Solution.

A (right). Bucket and homemade dipper holding one-half cupful. A wooden bucket is preferable, but galvanized iron can be used if carefully washed.

B (left). Hand-operated applicator especially designed for applying corrosive sublimate solution.

Photo by W. E. Tomlinson, Jr.

Number and Time of Applications. — Corrosive sublimate solution was applied at four periods one week apart beginning when the first eggs were found. These applications were timed in 15 combinations as shown in Table 11.

It is evident that two or more applications are necessary for consistently good control and that one of these applications must be made within a week after the first eggs are found (first or second period). More than two timely applications are unnecessary.

The control from one application was relatively unsatisfactory and extremely variable. In six years one application at the first period was more effective three times, and one application at the second period three times. One application at the third or fourth period (two or three weeks after the first eggs are found) was definitely unsatisfactory. With one exception good control was obtained from one application only when less than 80 percent of the untreated plants were commercially injured.

TABLE 11. RELATION OF TIME AND NUMBER OF APPLICATIONS OF CORROSIVE SUBLIMATE SOLUTION 1-1280 TO THE CONTROL OF CABBAGE MAGGOT. WALTHAM, MASSACHUSETTS, 1930-1943.

Number of Applications and Period When Applied*	Percent of Cabbage Plants Commercially Injured**														
	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	Average
One application															
1st	8.3		30.0	2.0	20.0	16.0	6.0	78.0	3.3	1.3	2.6	8.0			15.86
2d				6.0	52.0	6.0	70.0	20.0			0.0				25.67
3d				54.0	82.0	62.0	78.0	56.0							66.40
4th				44.0	90.0	88.0	80.0								75.40
Two applications															
1st and 2d			00.0	00.0		00.0	12.0	2.0	0.0	0.7	0.0	3.3	0.0	0.0	1.63
1st and 3d				00.0											
1st and 4th				00.0											
2d and 3d				00.0											
2d and 4th				00.0											
3d and 4th				22.0											
Three applications															
1st. 2d, and 3d			00.0	00.0											
1st, 2d, and 4th				00.0											
1st, 3d, and 4th				—											
2d, 3d, and 4th				00.0											
Four applications															
1st, 2d, 3d, and 4th		00.0	00.0	00.0											
None (Check)	33.0	75.0	96.0	57.0	86.0	98.3	88.0	95.0	77.3	87.3	68.0	85.7	79.0	77.0	78.75

*Period when applied:
1st — Not more than 1 day after first eggs were found
2d — 1 Week after first application
3d — 2 Weeks after first application
4th — 3 Weeks after first application

**Commercially injured — Plants showing moderate or severe injury or killed by maggot.

Semesan Suspension

Preliminary experiments in New York (5) have indicated that commercial organic mercury compounds gave relatively good control of cabbage maggot but they have been generally discarded for this purpose because of their high cost. In 1943 Semesan was used at the rate of 3 ounces in 10 gallons of water, making a dilution of organic mercury approximately equal to the dilution of corrosive sublimate in the 1-1280 formula. Two applications were made in the same manner and at the same time that corrosive sublimate solution was applied. The treatment gave 87 percent protection and 90 percent of the heads were marketable, but the material cost was two and one-half times greater than that for corrosive sublimate.

Experiments with Reduced Dosages

Because of the scarcity of mercury and the need of conserving vital materials during the war emergency, corrosive sublimate and calomel were used at reduced dosages in 1942 and 1943. The results are shown in Table 12.

TABLE 12. EXPERIMENTS WITH REDUCED DOSAGES OF MERCURY COMPOUNDS FOR COMBATING THE CABBAGE MAGGOT. VARIETY, GOLDEN ACRE CABBAGE. WALTHAM, MASSACHUSETTS, 1942-1943.

Material, Dilution, and Method of Application	Percent of Plants Showing— No Injury		Slight Injury		No Commercial Injury		Percent of Salable Heads	
	1942	1943	1942	1943	1942	1943	1942	1943
Corrosive Sublimate Solution 1-1280 1 oz. in 10 gals. water ½ cupful per plant 2 applications	52.2	61.8	47.8	39.2	100.0	100.0	87.8	86.7
Corrosive Sublimate Solution 1-1920 1 oz. in 15 gals. water ½ cupful per plant 2 applications	78.9	23.3	21.1	68.9	100.0	92.2	90.1	90.0
Corrosive Sublimate Solution 1-2560 1 oz. in 20 gals. water ½ cupful per plant 2 applications	—	11.1	—	74.5	—	85.6	—	84.4
Calomel-Talc Dust, 4 percent Calomel								
Mound Method*............	73.3	96.7	24.4	3.3	97.7	100.0	80.7	88.9
Duster Method**............	40.0	—	53.3	—	93.3	—	74.4	—
Calomel Talc Dust, 2 percent Calomel								
Mound Method*............	65.5	85.6	26.7	14.4	92.2	100.0	77.8	80.0
Duster Method**............	10.0	—	44.4	—	54.4	—	72.2	—
None (Check)..................	0.0	1.1	12.0	22.2	12.0	23.3	33.3	45.6

* See page 17 for description of the Mound Method of application.
** See page 16 for description of the Duster Method of application.

A dilution of corrosive sublimate 1-2560 (1 ounce in 20 gallons of water) protected 85 percent of the plants from commercial injury, but it was significantly less effective than the 1-1280 dilution. A dilution of 1-1920 (1 ounce in 15 gallons of water) was as effective as the standard 1-1280 dilution in 1942 and gave 92 percent protection from commercial injury in 1943. In fact, the percentage of salable heads where the greater dilution was applied was slightly greater in both years.

When calomel-talc dust was applied by the mound method, dusts containing both 4 percent and 2 percent calomel gave 100 percent protection from commercial injury in 1943 and were very effective in 1942. However, a slightly lower percentage of uninjured plants and salable heads in both years indicated that the 2 percent calomel content was near the limit of practical effectiveness and might give unsatisfactory protection with less careful application and less favorable growing conditions. When applied by the duster method, dust containing 2 percent calomel was definitely unsatisfactory in 1942.

DISCUSSION OF CONTROL TREATMENTS

The best treatment to use depends largely on the kind of equipment available, the responsibility of the labor for making a thorough application, and the degree of infestation. The most important factor is thoroughness of application, and the most effective treatments will not give satisfactory protection if they are applied carelessly. This is especially true of those treatments where only one application is recommended. A cost of ten dollars or less for the materials to treat an acre of 12,000 plants is considered reasonable, and there is a distinct advantage for the materials which require only one application.

Standard Treatments

Corrosive sublimate solution 1-1280 gives very good control of heavy infestations when two applications are made at weekly intervals. In light infestations one application is often satisfactory. Labor-saving equipment for applying is extremely helpful, but even when applied by the bucket-dipper method it is one of the most satisfactory treatments.

Calomel-talc dust 4 percent applied by the **mound method** is very effective and, since only one application is necessary, the material cost is slightly below the average. However, the dust must be placed carefully around the stem of each plant. Where responsible labor is available, this treatment is among the best.

Calomel-talc dust 4 percent applied by the **duster method** has the lowest material cost of any standard treatment and requires less than average labor per application. Three applications are necessary to give effective control of a heavy infestation, however, and the protection has not been consistently high.

Calomel-talc dust 50 percent, pre-transplanting method, is particularly adapted and recommended for use on plants which are transplanted with bare roots. The over-all cost is reasonable and the results are good. It is highly recommended for its special purpose.

Tar paper discs are very effective when carefully applied. The cost is high and careful application is slow and tiresome. They are very satisfactory for use in small home gardens, and are particularly recommended for that purpose.

TABLE 13. COMPARISON OF CHEMICAL TREATMENTS FOR FIELD CONTROL OF CABBAGE MAGGOT.

Treatment	Formula		Amount of Finished Insecticide Containing 1 lb. of Toxicant	Amount Applied per Plant	Effectiveness Rating	Number of Plants Treated with Material Containing 1 lb. of Toxicant	Number of Applications to Control Moderate to Severe Infestation	Approximate Cost for Materials per Acre*		Labor Requirements for Application
	Toxic Agent	Carrier						Per Application	Per Season	
Standard Treatments										
Corrosive Sublimate Solution 1-1280	Cor. Sub. 1 oz.	Water 10 gals.	160 gals.	½ cupful	Very good	5,120	2	$7.00	$14.00	High
Calomel-Talc Dust Mound Method	Calomel 4 percent	Talc 96 percent	25 lb.	1 teaspoonful	Very good	3,500	1	11.10	11.10	High
Calomel-Talc Dust Duster Method	Calomel 4 percent	Talc 96 percent	25 lb.	About 1/3 teaspoonful	Moderate	10,500	3	3.75	11.25	Moderate
Calomel-Talc Dust Pre-transplanting Method	Calomel 50 percent	Talc 50 percent	2 lb.	About 1/8 teaspoonful	Good	2,560	1	14.00	14.00	Low
Tar Paper Discs	Tar (repellant)	Paper	.....	1 disc (about 4 sq. in.)	Very good	......	1	24.00	24.00	High
Reduced Dosage Treatments										
Corrosive Sublimate Solution 1-1920	Cor. Sub. 1 oz.	Water 15 gals.	240 gals.	½ cupful	Good	7,680	2	$4.75	$9.50	High
Calomel-Talc Dust Mound Method	Calomel 2 percent	Talc 98 percent	50 lb.	1 teaspoonful	Good	7,000	1	6.00	6.00	High
Calomel-Talc Dust Duster Method	Calomel 2 percent	Talc 98 percent	50 lb.	About 1/3 teaspoonful	Poor	21,000	3	2.00	6.00	Moderate
Calomel-Talc Dust Pre-transplanting Method	Calomel 25 percent	Talc 75 percent	4 lb.	About 1/8 teaspoonful	Moderate	5,120	1	7.00	7.00	Low
Substitute Treatments										
Calomel-Gum 1-320	Calomel 4 oz.	Water 10 gals.	40 gals.	½ cupful	Very good	1,255	2	$30.00	$60.00	High
Semesan	Organic Mercury 3 oz.	Water 10 gals.	53 gals.	½ cupful	Good	1,696	2	17.50	35.00	High

*Based on 12,000 plants per acre, and a price of $3 per pound for corrosive sublimate and calomel, and 1 cent per pound for talc.

Reduced Dosage Treatments

Corrosive sublimate solution 1-1920 has given good protection at a reasonably low material cost. Two applications are nearly always advisable, and the material must be applied very carefully. It is the most reliable of the reduced dosage treatments and is highly recommended where a moderate or light infestation is expected. It can be used successfully in place of the standard corrosive sublimate solution 1-1280 wherever the application is reasonably thorough.

Calomel–talc dust 2 percent, mound method, has given good protection in the two years that it has been used. However, there is evidence that it will be satisfactory only if the dust is placed around the stem of each plant **very carefully.** The material cost is the lowest of all treatments. When applied by average farm labor, the use of calomel-talc dust 4 percent will probably be more desirable.

Calomel–talc dust 2 percent, duster method, was used only in 1942 and gave only 54 percent protection. In spite of a very low material cost, the need for three applications builds up a moderate labor cost. It is not recommended unless calomel–talc dust 4 percent is unavailable.

Calomel–talc dust 25 percent, pre-transplanting method, like the standard pre-transplanting treatment, is limited in its use. In four years it has been only slightly less effective than the 50 percent calomel–talc dust used in the same way. The material cost and the labor cost are both very low, and where the anticipated infestation is moderate or light it should be as satisfactory as the stronger dust.

Substitute Treatments

Calomel–gum suspension 1-320 gave complete protection in 1940. However, the material cost is extremely high and the preparation of a homemade suspension is too complicated for the average farmer. If a commercial preparation was available at a reasonable cost, it would undoubtedly be a satisfactory substitute for corrosive sublimate solution.

Semesan suspension, when prepared by adding 3 ounces of Semesan to 10 gallons of water to provide a mercury content equal to the standard corrosive sublimate solution, gave good protection in 1943. However, the cost is very high and it is recommended only when other materials are unavailable.

CABBAGE MAGGOT IN RADISHES

Since the edible portion of radish, turnip, and kohlrabi is attacked, control of the cabbage maggot in these vegetables must be perfect. In the experiments on radishes at Waltham, complete protection was not secured and no practical chemical treatment was discovered. The standard treatments with corrosive sublimate solution and calomel–talc dust, which were used on cabbage, reduced the injury to radish but permitted 20 to 50 percent of the plants to be infested and caused some injury to the foliage and roots. Furthermore, these materials are poisonous and treatment with them cannot be recommended freely because the edible portion of the plant is exposed to the chemical. Rotenone dust was not significantly effective.

Planting experiments at Waltham indicated that fast-growing radishes of the Scarlet Globe type, which mature in about 30 days from the time the seed is sown, can be grown with little injury from the cabbage maggot between the active periods of this insect. As shown in Table 14, little injury resulted when the seed was sown from May 25 to June 5, or after July 10. Although no seed was sown before May 1, radishes planted before April 10 should escape serious injury; but those from seed planted between April 15 and May 1 would be heavily infested. Under eastern Massachusetts conditions, early radishes must be protected by a cheesecloth screen after May 10 to avoid injury by the cabbage maggot.

TABLE 14. RELATION OF DATE OF PLANTING CAVALIER RADISH TO INJURY BY THE CABBAGE MAGGOT. WALTHAM, MASSACHUSETTS, 1938-1939.

Date Seed Sown	Percent of Radishes Infested			Date Seed Sown	Percent of Radishes Infested		
	1938	1939	Average		1938	1939	Average
May 1–2.........	37	29	33.0	June 30–July 2.....	12	30	21.0
May 10–12.......	16	45	30.5	July 10–12.........	1	5	3.0
May 20–23.......	12	42	27.0	July 20–25.........	3	2	2.5
May 29–June 2...	5	2	3.5	August 2...........	0	—	0.0
June 10–14......	18	59	38.5	August 15.........	2	—	2.0
June 20–22......	44	44	44.0	August 30.........	—	15	15.0
				September 10......	—	4	4.0

SUMMARY

The cabbage maggot, a native of Europe, is now well established in North America, where it is a destructive pest of cruciferous plants in the cooler regions. It belongs to the family *Anthomyiidae* and is named *Hylemya brassicae* Bouché. The egg, larva, pupa, and adult stages are briefly described and illustrated. There are three generations annually, of which the first is the most destructive to early cabbage and similar crops, while the third often damages late turnips and radishes seriously.

It attacks all cruciferous plants and has been reported feeding on celery and beets. The relative susceptibility of the common cruciferous vegetables is shown, and experiments to determine resistance among cabbage varieties, in which Early Jersey Wakefield has been outstanding, are reported.

Injury to plants is caused by the feeding of the maggot, and badly infested plants become gray in color, wilt, and usually die. Moderately infested plants may recover in cool weather by developing secondary roots as illustrated. On radish, turnip, and kohlrabi, in which the root is edible, slight maggot injury makes the plant worthless.

Rotation of cruciferous crops, fall plowing, and similar cultural practices reduce the losses from this pest; and all cabbage stumps and infested turnips, which are the source of spring infestations, should be destroyed before winter.

Control treatments, to be successful, should be based on the activity of the insect. In these studies they have been correlated with the time when the first eggs were laid, which occurred between April 29 and May 10 in the thirteen-year period, 1931-1943.

In the last fourteen years at Waltham, 78.7 percent of the untreated cabbage plants have been commercially injured, and the natural infestation has been less than 75 percent in only three of these years.

The recommended seedbed treatments to prevent loss from this pest are to cover the bed with cheesecloth, or to apply corrosive sublimate solution 1-1920 at the rate of 1 gallon to 40 feet of row three or four times at weekly intervals while the flies are laying eggs.

Pre-transplanting treatments applied by coating the lower stem and roots with calomel–talc equal parts, or calomel 1 part and talc 3 parts, have been effective and are recommended on plants which are transplanted with bare roots. Dipping these plants in a calomel–water suspension containing various adhesives was unsatisfactory.

Field treatments for cabbage maggot control are divided into repellents, toxic dusts, and toxic liquid drenches.

Among the repellents, tar paper discs gave excellent control when carefully applied, and are recommended for use in home gardens especially. Mulch paper increased plant growth 17 to 32 percent but provided poor protection and is not considered practical for cabbage maggot control.

Among the insecticidal dusts, naphthalene flakes were effective if the application was repeated frequently, but they are not advised for large-scale treatments. Rotenone dusts were not satisfactory as used. Calomel–talc dust, 4 percent calomel, applied by the duster method was moderately effective and satisfactory if the infestation was light. When this dust was applied by the mound method, it was one of the best treatments used.

Liquid drenches of calomel–gum suspension and Semesan gave satisfactory control but are expensive and the former is difficult to prepare. Corrosive sublimate solution, prepared by dissolving corrosive sublimate powder, crystals, or tablets in water, is the standard material for combating the cabbage maggot. The most effective solution contains 1 ounce of the chemical in 10 gallons of water, a dilution of 1-1280, but experiments have shown that a 1-1920 dilution is satisfactory if carefully applied. Two applications, at the rate of one-half cupful per plant, at weekly intervals, are advisable if the infestation is heavy; but one application is often sufficient to control a light infestation. The first application should be made within a week after the first eggs are laid, and more than two timely applications are unnecessary. The solution is applied with a bucket and dipper, a watering pot, and various mechanical devices. An especially designed applicator was used successfully at Waltham.

Experiments in 1942 and 1943, with reduced dosages which would conserve material during the war emergency, indicate that corrosive sublimate solution 1-1920 and calomel–talc dust, 2 percent calomel, applied by the mound method are effective if the application is made carefully. Calomel–talc dust, 2 percent calomel, applied by the duster method was not effective, and corrosive sublimate solution 1-2560 permitted a large increase in the number of slightly injured plants.

The cost and practical value of the recommended treatments are discussed and summarized in Table 13.

An effective control of the cabbage maggot in radishes was not discovered, but relatively small losses occurred if the seed was planted between May 25 and June 5, or after July 10.

LITERATURE CITED

1. Brittain, W. H. Experiments in the control of the cabbage maggot (*Chortophila brassicae* Bouché) in 1920. Proc. Ent. Soc. of Nova Scotia (1920): 54-74. 1921.
2. Caffrey, D. J. The cabbage maggot. U. S. Dept. Agr. Bur. Ent. and Pl. Quar. Mimeo. E-336. 1935.
3. Chittenden, F. H. Some insects injurious to vegetable crops. U. S. Dept. Agr., Div. Ent. Bul. 33, New Series, p. 90. 1902.
4. Clayton, E. E. Control of seedbed diseases of cruciferous crops on Long Island by the mercuric chloride treatment for cabbage maggot. N. Y. State Agr. Expt. Sta. Bul. 537:1-29. 1926.
5. Glasgow, H. Control of the cabbage maggot in the seedbed. N. Y. State Agr. Expt. Sta. Bul 512:1-112. 1925.
6. ————————. Common insect pests of New York (6), the cabbage root maggot. N. Y. State Agr. Expt. Sta. Circ. 164 (rev.).
7. Guba, E. F., and Whitcomb, W. D. Control calendar for vegetable pests. Mass. State Col. Ext. Leaflet 116:1-24. Rev. April 1941.
8. Metcalf, C. L., and Flint, W. P. Destructive and useful insects. McGraw Hill Book Co., Inc., 981 pp. 1939. (Lit. Cit. p. 542.)

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

AUG 12 1944

Bulletin No. 413 March, 1944

The Identification of Plum Varieties From Non-Bearing Trees

By Lawrence Southwick and A. P. French

The identification of varieties before fruit trees leave the nursery is important if disappointments in the orchard are to be avoided. This bulletin considers the characteristics by which nursery plum trees may be identified and records descriptions and photographs of 57 varieties.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE IDENTIFICATION OF PLUM VARIETIES FROM NON-BEARING TREES

By Lawrence Southwick, Research Assistant in Pomology,
and A. P. French, Professor of Pomology[1]

This bulletin is the fifth in a series on the identification of fruit varieties from nursery and non-bearing trees. Papers relating to apples and cherries have been published (2) (4) (5) (6).

Although it is true that apples and cherries have been mixed in commercial nurseries rather more generally than plums, yet in the experience of the authors, mixtures in plums are not infrequently observed. This has led in recent years, in most nurseries visited, to as careful annual inspection of plums in the nursery row as of apples and cherries. Not only have mixtures been found in the old standard sorts, but in some cases varieties recently named and introduced have been found misnamed in their entirety or mixed with other varieties. Hence, the need is apparent for information which may help to eliminate such mixtures. This bulletin records in words and pictures much of the information necessary to distinguish plum varieties from one another. The list of varieties included in this study is not complete by any means, but a majority of the plums now found in commercial nurseries are included as well as some less known old varieties and a number of the newer ones.

Previous publications dealing with varietal differences of plum varieties as nursery trees are few. Upshall (8) has briefly described some of the more important varieties. Shoemaker (7) has made some further comparisons using shoots from bearing trees.

It should be stressed here that the characteristics of nursery trees cannot be learned satisfactorily from printed descriptions or even pictures. Much time must be spent in close observation of nursery trees that are known to be true to to name before one can positively identify varieties and accurately separate mixtures in the nursery row. This bulletin should aid materially in the acquisition of such a working knowledge.

All of the descriptions and pictures in this bulletin were derived from one- and two-year budded trees growing in the Experiment Station nurseries at Amherst. In a few cases, only one-year trees were available. Every effort was made to establish the identity of each variety used in this study. The sources of budwood include the New York State Agricultural Experiment Station at Geneva, the Minnesota Agricultural Experiment Station at St. Paul, the Ontario Horticultural Experiment Station at Vineland, and our own bearing trees at Amherst.

Confusion of Names Among Plum Varieties

PRUNES

Hedrick (3) mentions several strains of German Prune, two of which (the Rochester strain and the Dansville strain) he suggests are more or less frequently found in the nurseries of New York State. The German Prune herein considered is the same as that described by him as the Rochester strain and is the common German Prune of the nursery trade. In the opinion of the writers, the Dansville strain of German Prune (fruit of which Hedrick was unable to obtain) was nothing more or less than Italian Prune. Some years ago several lots of "German Prune"

---

[1] The writers are indebted to Dr. J. K. Shaw for much valuable counsel both in the field work and in the preparation of the manuscript, and to Professor O. C. Roberts for assistance in obtaining the field data.

trees were seen in nurseries around Dansville, New York, which were indistinguishable from Italian Prune trees in the same nurseries. Furthermore, when planted in the orchard, these trees bore fruits which were indistinguishable from Italian Prune. It would be most unusual for a variety as distinct as German Prune to produce a bud sport so closely resembling another variety in both fruit and tree characters.

The York State Prune, which is supposed to have originated as a seedling, has been reported by Hedrick and others to be identical in fruit with Italian Prune and the writers have found the same to be true for its tree characters. This being the case, one wonders whether it really originated as a seedling or whether it may have been a nursery-grown tree which remained to fruit on abandoned nursery land. Such trees are not too uncommon in a section that has been in the nursery business as long as has that around Dansville.

THE REINE CLAUDE OR GREEN GAGE PLUMS

The nomenclature of this group of plums is notoriously filled with synonyms. This fact is not surprising when one recalls that the term Reine Claude may be used with reference to the group as a whole and is at least a part of the name of several of the varieties within the group, and furthermore that the term Gage is the English synonym for Reine Claude as used in continental Europe.

Hedrick noted that Bavay was called the true Reine Claude variety by many nurserymen, and it is unfortunately true today that most nurserymen grow Bavay under the name of Reine Claude or Green Gage. The Green Gage described in this bulletin was obtained from the New York State Agricultural Experiment Station at Geneva and is distinctly different from Bavay. This Green Gage, which presumably is the genuine Reine Claude variety, has never been found by the writers in a commercial nursery.

SHROPSHIRE DAMSON PLUMS

The Shropshire Damson plum in common cultivation in this country is described in this bulletin under the name Shropshire. The English Shropshire is grown in England but is practically non-existent in the United States. The source of budwood of this variety was the Ontario Horticultural Experiment Station at Vineland, Ontario, Canada.

Inspection or Examination of Nursery Trees for Trueness-to-Name

The inspection of nursery trees for trueness-to-name is done usually in midsummer. Experience has shown that, in general, varietal differences are most apparent in trees that are in active growth. When growth slows down as it often does in late summer and fall, some of the most useful distinguishing characteristics of varieties are lost. However, some characters persist until frost and freezing weather. Furthermore, it should be understood that there is no one time when all of the important distinguishing characteristics are obvious. It is often worth while to study trees throughout the growing season in order to observe the degrees of variation in the prominence of certain vegetative characteristics. For instance, the color of a growing tip or a shoot may vary considerably from early to late summer depending on relative rates of growth, temperature, amount of shading, and other factors of environment. Nevertheless, experience has again shown that when a character is altered by environment, the several varieties usually maintain their relative order for that character. Hence, it is entirely feasible to examine nursery trees for trueness-to-name over a rather extended period during the growing season. Since early-season inspection gives opportunity to detect mixtures before budwood is desired for propagation and since the relative freedom from insect and disease damage at this time tends to facilitate rapid inspection, the writers and their colleagues have in recent years examined fruit nursery stock for trueness-to-name during the month of July so far as possible.

Nursery trees often vary in appearance when growing in widely separated localities. However, though the usefulness of particular characters may vary, the identification of varieties in the nursery row is feasible no matter where grown so long as good growth is being made.

How Plum Varieties Differ

There are many plant characters of importance in distinguishing one variety from another. Sometimes the presence of a single character is sufficient for positive identification; more often several to many characters are considered. Those found most useful are briefly described here. In the accompanying illustrations (Figures 1-11), specimens have been chosen to emphasize some of the more important distinguishing characteristics.

The *habit of growth* usually refers to the direction and length of individual shoots of two-year trees. It may vary from spreading to upright, with most varieties falling in the classification of upright-spreading. Tree height and stoutness of branches and shoots may refer to both one- and two-year trees. Sometimes the length of internode, space between buds along a shoot, is of some value.

The *bark* may be of value in both one-and two -year trees. Two-year trunk bark varies from light brown as in Yellow Egg, through medium brown as in Bavay, greenish brown as in Wickson, and gray brown as in Beauty, to dark brown as in American Mirabelle. Bark color is a variable character, but in general, varietal differences are worth noting. One-year bark is usually more green, purple, and red and less brown than two-year bark, although the characteristic color of the latter is approached near the base of a one-year tree.

The *color of young shoots* is usually greenish at least near the growing tips. Lower down, the older parts of shoots may take on some other color, usually a red or purplish tinge. The amount of this coloration varies not only with shoot age but also with tree vigor and other factors. However, the color of young shoots is often a very valuable varietal characteristic. When shoot color is mentioned in the descriptions, it usually refers to the color of these young shoots. Older shoots gradually assume the features of one-year bark.

The *surface character of bark* is often important (Figure 1). Elephant Heart is glabrous or without pubescence or hairs; it is very smooth and even glossy. Bradshaw appears glaucous due to a very fine pebbling of the bark. It is not true glaucousness. Shropshire has true scarfskin which checks and can be scraped off easily leaving the bark smooth; Beauty has a netted russet epidermis, while on Burbank it is ridged. In Beauty and Burbank, it is not easily scraped off and does not leave smooth bark below. The *lenticels* on both shoots and older bark may differ in number, size, and color. Although they often do not vary sufficiently to aid in identification, in some cases they are helpful. For example, the number varies from very few as on Blue Rex Damson to very many as on Santa Rosa. They are usually flush, but Monitor and a few other varieties have raised lenticels that feel rough to the touch. Lenticels may be inconspicuous as on Elephant Heart or conspicuous as on Red June. Although usually russet in color, they may be whitish as on French Damson. Lenticels are more useful with Japanese than with European varieties.

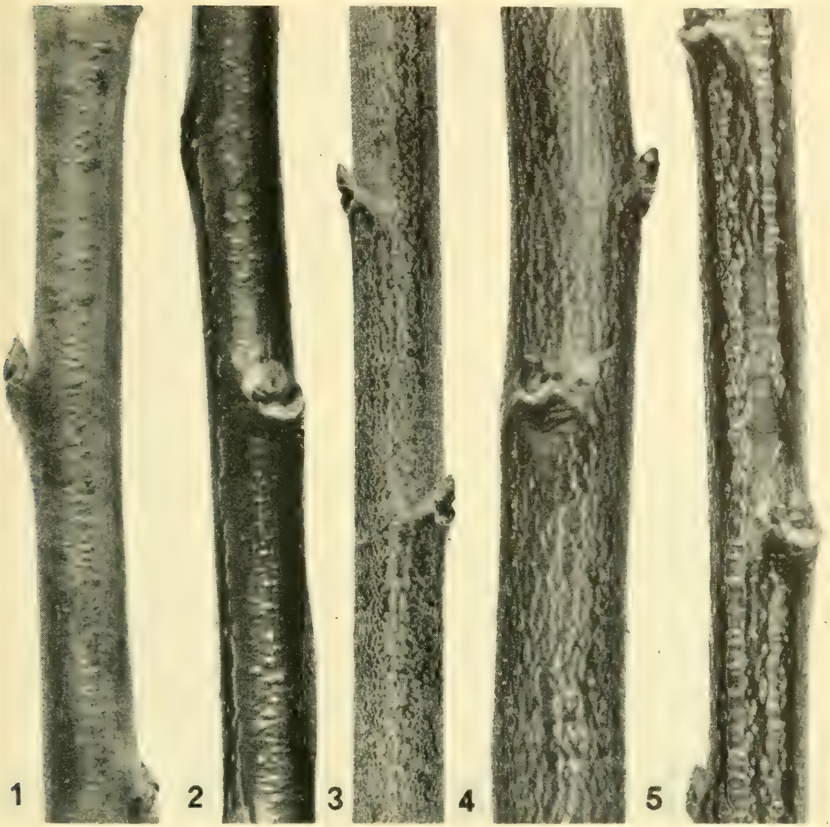


Figure 1. Bark. (2 ×)

1. **BRADSHAW** — pseudoglaucousness due to very finely pebbled bark;
2. **ELEPHANT HEART** — glabrous, smooth, and glossy;
3. **SHROPSHIRE** — true scarfskin;
4. **BEAUTY** — netted, russet epidermis;
5. **BURBANK** — ridged, russet epidermis.

The *shoot pubescence* is one of the more important characters. Shoots may lack pubescence as in Lombard, have a medium amount as in Field, or be heavily pubescent as in Monarch (Figure 2). Hedrick (3) and Shoemaker (7) have published data on pubescence that are somewhat at variance with the data given in this bulletin. In particular, some of the European varieties that they have described as having pubescent shoots are described herein as essentially glabrous. However, both Hedrick and Shoemaker studied shoots from bearing trees and it is apparent that pubescence on such shoots is not always the same as that on shoots of nursery trees.

The *color of the growing tips* is a valuable character for recognition. To be most valuable, observation should be made while shoots are making active length growth, as in the early part of the growing season. The small young unfolding leaves at the shoot tips vary in color from the yellowish green of

Elephant Heart through the light green of Early Laxton, the green of Abundance, and the reddish tinge of Beauty to the dull red of Underwood and the bright red of Pearl. Varieties also differ in the *color of the young leaves* a little back from the tip although this character is neither so significant nor so characteristic as the color of the tips. However, the color may range from very light yellowish green in Elephant Heart through light green in De Montfort to rather dark green in Glass. Sometimes these leaves are more or less characteristically bronzed as in Pipestone.

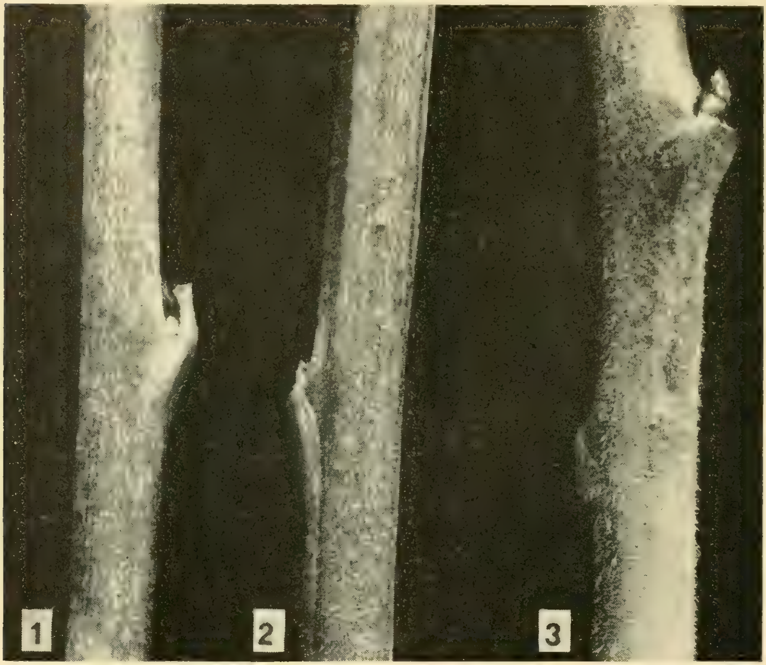


Figure 2. Shoot Pubescence. (2 ×)

1. LOMBARD — none; 2. FIELD — medium; 3. MONARCH — heavy.

The *petiole* is fairly important as a distinguishing varietal character in plums. The angle that the petiole makes with an upright shoot is usually wide, i. e., approaching a right angle. However, in some varieties the petioles are often medium-angled as in Formosa or occasionally moderately narrow-angled as in Elliot. Usually the Japanese plums have more nearly upright leaves than the European. Petioles are usually straight but sometimes are upcurving as in American Mirabelle. They may also vary in length, thickness, and color. A petiole may be typically short and thick as in Washington, short and slender as in Imperial Epineuse, or rather long as in Monitor. Its color varies from essentially green as in Glass, through reddish tinged as in Imperial Gage and reddish as in Gueii, to red as in Field. Color is not a constant character, being influenced by vigor, age, and environment. However, with these limitations kept in mind, petiole coloration can be very useful in assisting in the identification of some varieties.

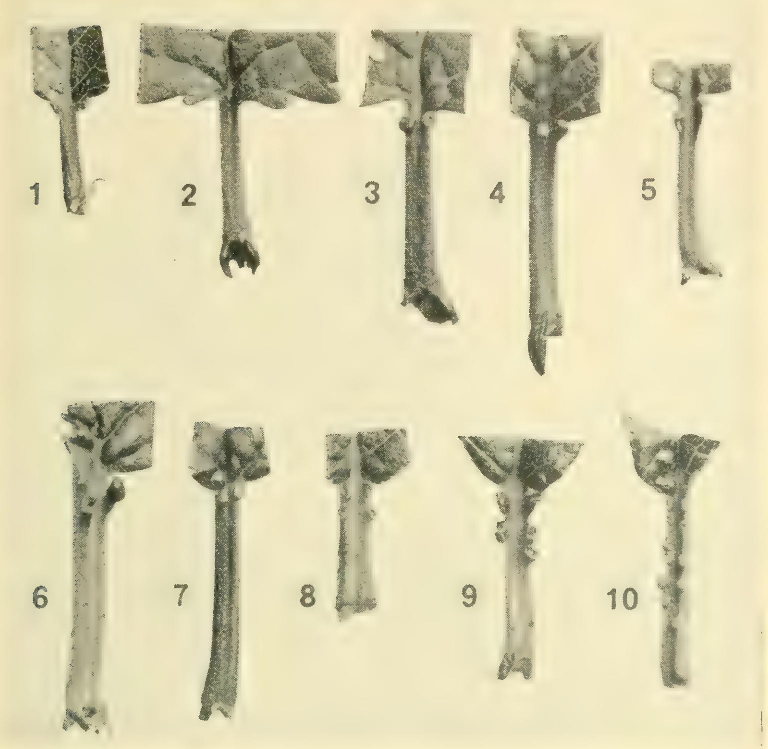


Figure 3. Glands. (2 ×)

1. **SANTA ROSA — 2, small, reniform, on the blade;**
2. **GERMAN PRUNE — 2, small, round, on the blade;**
3. **IMPERIAL GAGE — 2, medium in size, round, on the petiole, with depressed centers;**
4. **IMPERIAL EPINEUSE — 2, rather small, round, stalked, close to the blade;**
5. **PEARL — 2, rather small, usually round, leafy-stalked, on the petiole;**
6. **CALIFORNIA BLUE — 2, large, reniform, stalked, down on the petiole;**
7. **MONITOR — 2, medium in size, reniform, close to the blade;**
8. **ABUNDANCE — 2-4, medium in size, reniform, scattered;**
9. **BURBANK — 2-6, medium in size, mostly reniform, scattered;**
10. **FORMOSA — numerous, moderately small, round, scattered.**

The *glands* are extremely valuable characters in the identification of plum varieties. Glands vary in number, size, shape, and position as illustrated in Figure 3. They are usually 2 in number and are placed side by side on the upper surface of the petiole close to the blade; but with some plums, particularly Japanese, the gland number is typically more than 2. Abundance has 2-4, Burbank 2-6, and Formosa many. Glands are apt to be rather small but with many varieties they are medium-sized, and with a few, as California Blue, they are large. The globose or round gland shape is most general, but reniform or kidney-shaped glands are not uncommon as in California Blue, Santa Rosa, Abundance, and others. A few varieties have more or less stalked or leafy-stalked glands as in Imperial Epineuse and Pearl, respectively (see Figure 3). Further, glands may be pitted or have depressed centers as in Imperial Gage. Gland position is worth noting. They may be on the blade as in German Prune, close to the blade as in many varieties, somewhat down on the petiole as in California Blue, or scattered along the petiole as in Formosa. The color of the glands is sometimes useful, varying from green as in Sannois to yellowish as in Agen, and occasionally somewhat reddish as in Pearl.

The *leaf blade* is very important. The various characteristics will be treated separately.

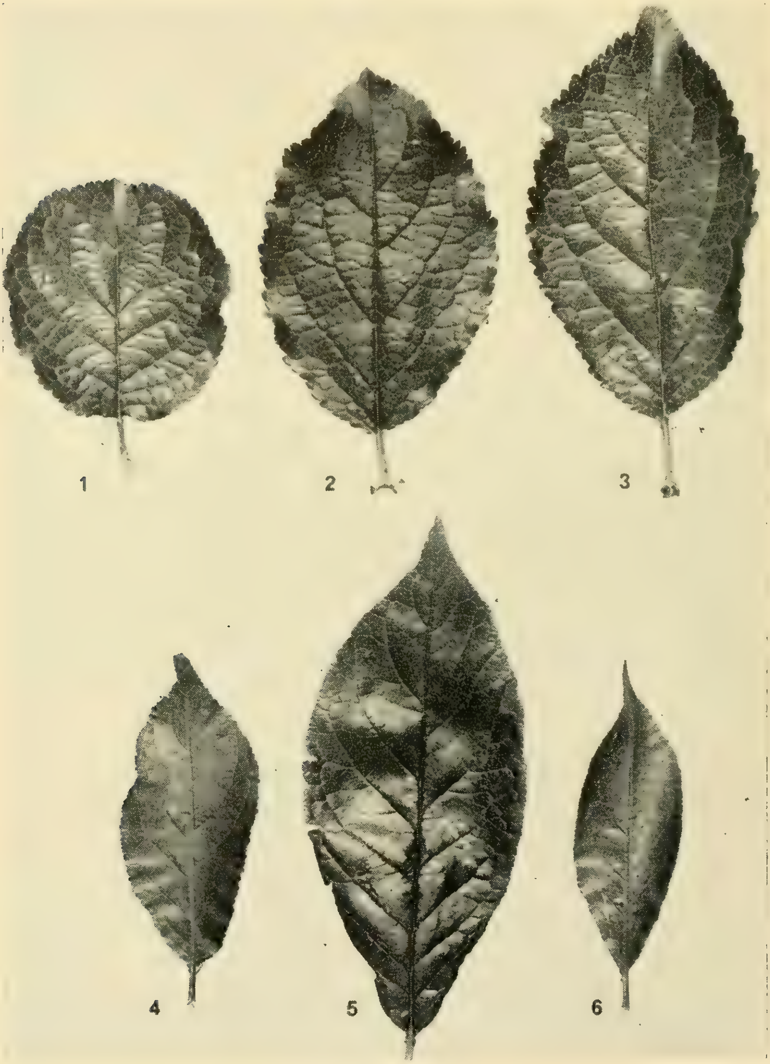


Figure 4. Leaf Shape.

1. **MONARCH** — roundish;
2. **HALL** — oval;
3. **ITALIAN** — obovate;
4. **RED JUNE** — elliptic;
5. **BURBANK** — long obovate;
6. **WICKSON** — narrow elliptic.

The *size* of individual leaves is often influenced materially by the vigor of growth of a tree. Nevertheless, leaf size differences are quite dependable between varieties. Average size of the blade varies from small in Shropshire and American Mirabelle to large in Field and Washington.

Leaf shape may be roundish as in Monarch, oval as in Hall and the majority of varieties, obovate as in Italian, long-obovate as in Burbank, elliptic as in Red June, or narrow elliptic as in Wickson (Figure 4).

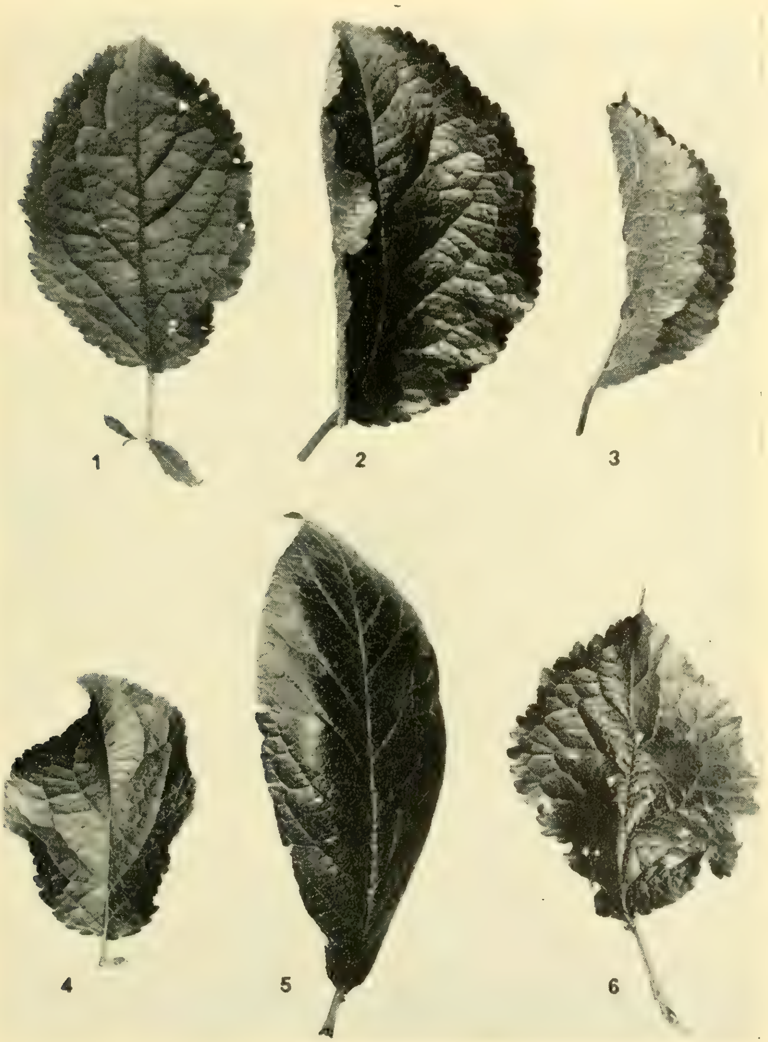


Figure 5. Leaf Folding.

1. **HALL**—flat;
2. **BAVAY**—broad U-folded;
3. **STANLEY**—narrow U-folded;
4. **ALBION**—broad V-folded;
5. **BURBANK** — reverse saucer-folded;
6. **BRADSHAW**—reverse keel-folded, with twisted midrib.

Most leaves show some degree of *folding*, but the amount and type differs with the variety (Figure 5). With some plums, the leaves are usually flat as in Hall. Broad U-folding as in Bavay is very common while narrow U-folding as in Stanley is sometimes found. With some varieties, the upward folding of the leaf seems to be more characteristically V-shaped as in Albion although the difference between U-folding and V-folding is sometimes not uniformly distinct. De Montfort leaves are often saucer-folded while a reverse-saucer folding is characteristic of some varieties such as Burbank. The Bradshaw fold as shown in Figure 5 is very distinctive. It has been the experience of the writers that leaf-folding is a very useful character in identification work. However, it should be emphasized that such a character is profoundly influenced by environmental conditions and much experience is necessary before one can know how much dependence to place on it at any particular time or place.

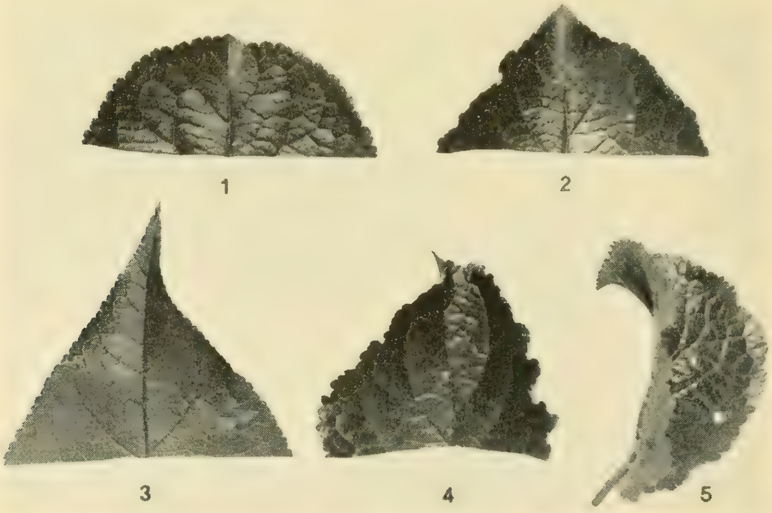


Figure 6. Leaf Tip.

1. **MONARCH — mucronate;**
2. **YELLOW GAGE — acute;**
3. **MONITOR — acuminate;**
4. **LOMBARD — twisted;**
5. **PEARL — reflexed.**

The *leaf tip* may be of considerable value (Figure 6). Commonly, the tip is acute as in Yellow Gage, but it may be mucronate (very short and abrupt) as in Monarch, or acuminate (long-pointed) as in Monitor. Some tips are characteristically twisted as in Lombard or reflexed as in Pearl. Sometimes the point of the tip is a useful character. For example, the point is sharp in Shropshire and dull or round in English Shropshire.

The *leaf margin* in plums is rarely even or without any waving as in Monitor (Figure 7). With some varieties, as Albion, the waving is coarse; while with others, as German Prune, it is fine; and many varieties show medium waving. Also, there is wide variation in the amount of any kind of waving. This will vary from slight to much and is an important feature to observe along with the type of waving.

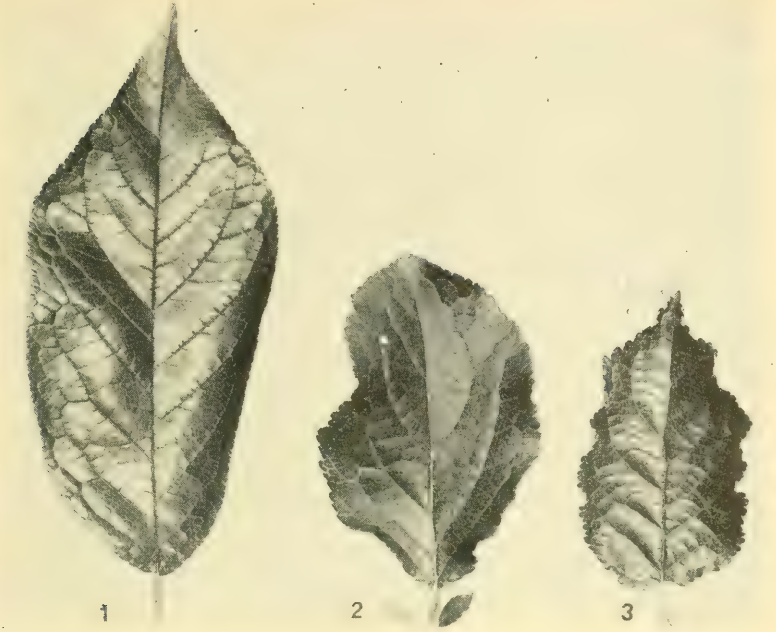


Figure 7. Leaf Margin.

1. MONITOR — even; 2. ALBION — coarsely waved; 3. GERMAN PRUNE — finely waved.

The *nature of the upper surface* of the leaf is worthy of careful note (Figures 8 and 9). It may be smooth as in Wickson, slightly bullate or pebbled as in French Damson, very bullate as in Pearl, slightly rugose or wrinkled as in Shropshire or quite rugose as in English Shropshire. Furthermore, the leaves of some varieties have pubescence on the upper surface. This is particularly true of the

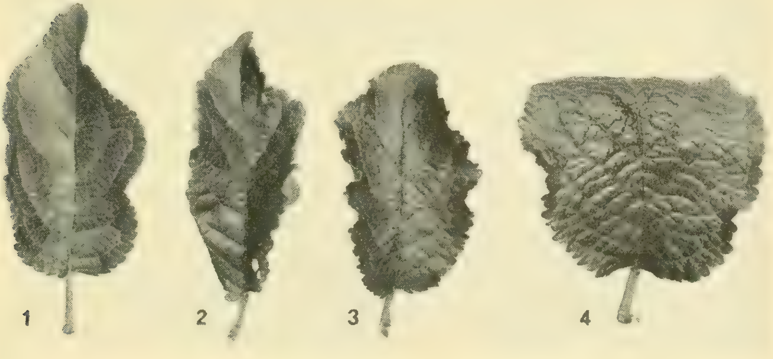


Figure 8. Leaf Surface.

1. SHROPSHIRE — slightly rugose;
2. ENGLISH SHROPSHIRE — rugose;
3. FRENCH DAMSON — slightly bullate;
4. PEARL — bullate.

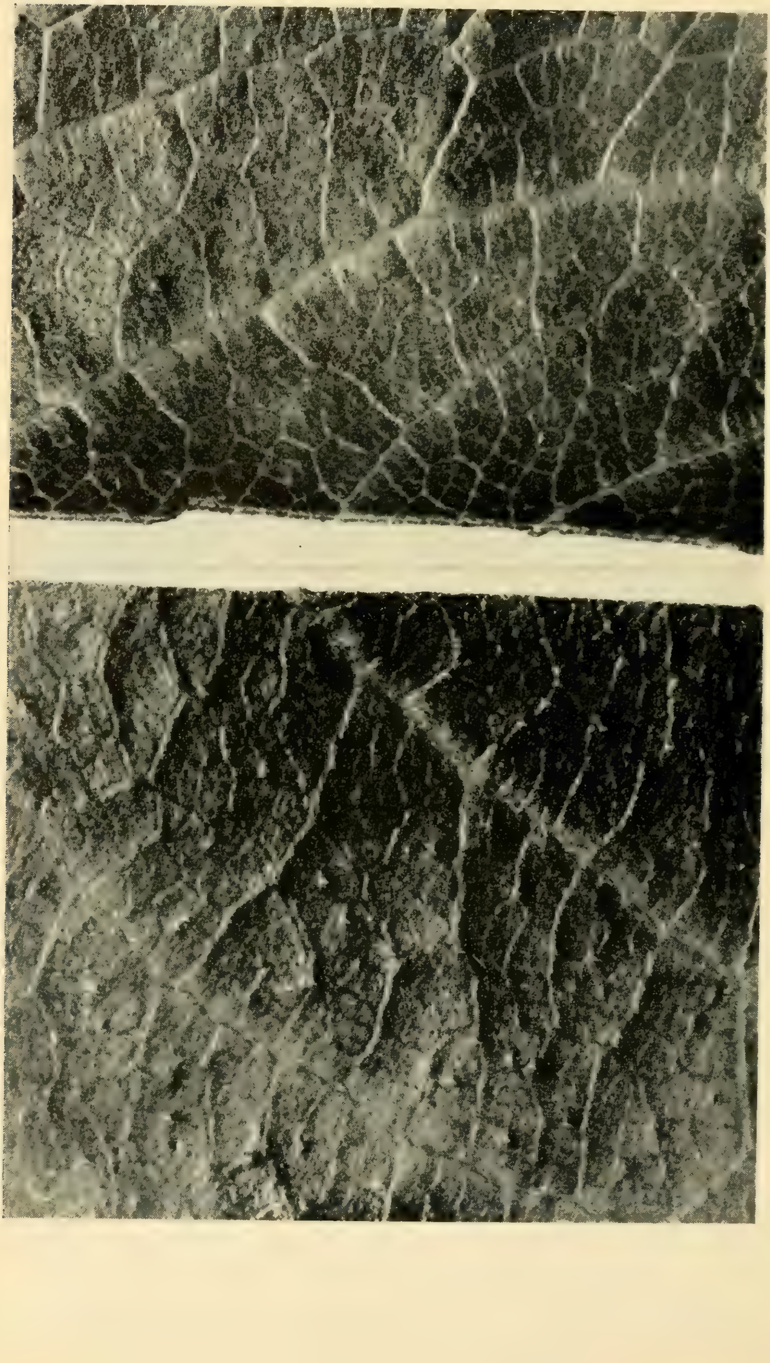


Figure 9. Leaf Surface. (6 ×)
Left: BEAUTY — hirsute or bristly; Right: WICKSON — smooth.

more mature leaves. This pubescence is usually very fine and is often rather difficult to observe except on a few varieties, as Early Laxton, where it is quite prominent. Furthermore, the length and location of pubescence is variable. For instance, Yellow Egg and Italian Prune have quite long hairs. Those of Yellow Egg are on the surface of the blade tissue while those of Italian Prune are fewer and confined to the midrib and principal veins. Occasionally the pubescence is coarse and stiff — hirsute — and the upper leaf surface feels bristly or gritty to the touch as in Beauty (Figure 9).

The *amount of light reflection* from leaves is variable, depending not only on variety but also on leaf age, time of observation during the growing season, amount of dust on the leaf surface, and brightness of the day. Despite these secondary influences, light reflection can still be a valuable distinctive character (Figure 10). President and Glass are described as very glossy or shiny. A number of varieties, as Golden Drop, are usually semi-glossy, and others, as Early Laxton, are dull. With one variety, Elephant Heart, many leaves are waxy-glossy.

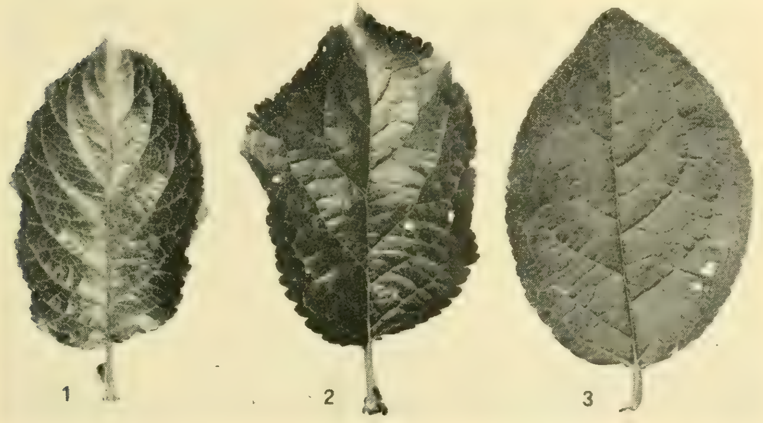


Figure 10. Light Reflection.

1. PRESIDENT—glossy; 2. GOLDEN DROP—semi-glossy; 3. EARLY LAXTON—dull.

Although *leaf color* may be influenced considerably by environmental conditions, particularly nutrition, this character is one of the first that is taken into consideration when examining nursery trees. When its limitations are fully realized, its value in identification work is great. The color of fully developed leaves on vigorous shoots may be typically light green as in Early Laxton, medium green as in Bavay, rather dark green as in Albion or dark green as in Glass. Also, there is a good deal of yellow in the leaves of some varieties. Thus Burbank is described as medium yellowish green and Italian Prune as dark yellowish green.

Late fall coloration may be useful with the Japanese and some hybrid varieties. For instance, while Santa Rosa remains green, and Elephant Heart foliage usually turns slightly red, that of Red June becomes almost uniformly red. The following tabulation gives the fall foliage coloration for the year 1943.

Variety	*Late Fall Foliage Coloration*	*Variety*	*Late Fall Foliage Coloration*
Abundance	red	Pipestone	red
Beauty	green	Red Coat	some red, variable
Burbank	red	Red June	red
Elephant Heart	slightly red	Santa Rosa	very green
Elliot	red	Shiro	green
Ember	red	Superior	slightly red
Formosa	red	Underwood	greenish
Methley	medium red	Wickson	very green
Monitor	red	Wright's Early	red

The *serrations* or teeth along the leaf margins are worth noting (Figure 11). Serrations may be coarse, as in American Mirabelle, medium as in Italian Prune, or fine as in Abundance. They may also be deep as in Stanley, medium in depth as in German Prune, shallow as in Abundance, or very shallow and indistinct as in Burbank. In a number of varieties, many of the individual serratures are double or divided in two. In a few sorts, as Italian Prune, there may be considerable tripling. Plum serrations are not often as sharply serrate (sharp-pointed) as they are in President. They are more likely to be dull serrate as in the varieties in the top part of Figure 11, or crenate (rounded) as in the varieties illustrated just below. There is also some variation in the regularity of serrations which may be of occasional value.

The *leaf pose* or the general position taken by the shoot leaves is characteristic of the variety. It is determined largely by the angle of the petiole with the shoot, and the amount of reflexion of both the petiole and the leaf midrib. The amount and type of folding of the blade also plays a part. The leaf pose of a nursery tree is undoubtedly one of the most significant characters used in variety identification in the field because it gives at a glance a composite picture of several plant characteristics as just mentioned. It is because of the unusual importance in identification work of the general appearance of whole shoots of plums that photographs of typical shoots of all the varieties described in this bulletin are included in the next section.

Illustrations and Comments on the Prominent Characteristics of Plum Varieties

The following pages show illustrations of the upper portions — approximately 2 feet — of one-year shoot growths of plum trees as they grow in the nursery. Most of the shoots are from one-year whips although some were taken from strong-growing two-year trees. The shoots photographed were as typical of the variety as could be obtained.

In connection with the illustrations, some of the prominent characteristics of each variety are listed. These characteristics have been found to be particularly valuable in variety identification in the field although some of them are more outstanding than others in particular varieties. However, all of them are useful, especially in conjunction with the accompanying photographs. In many cases, of course, the more complete descriptions in the back part of this bulletin will be found useful and perhaps necessary for positive identification of some varieties. And under certain circumstances one or more of the characteristics not listed here as prominent may be even more valuable than some of those that are listed.

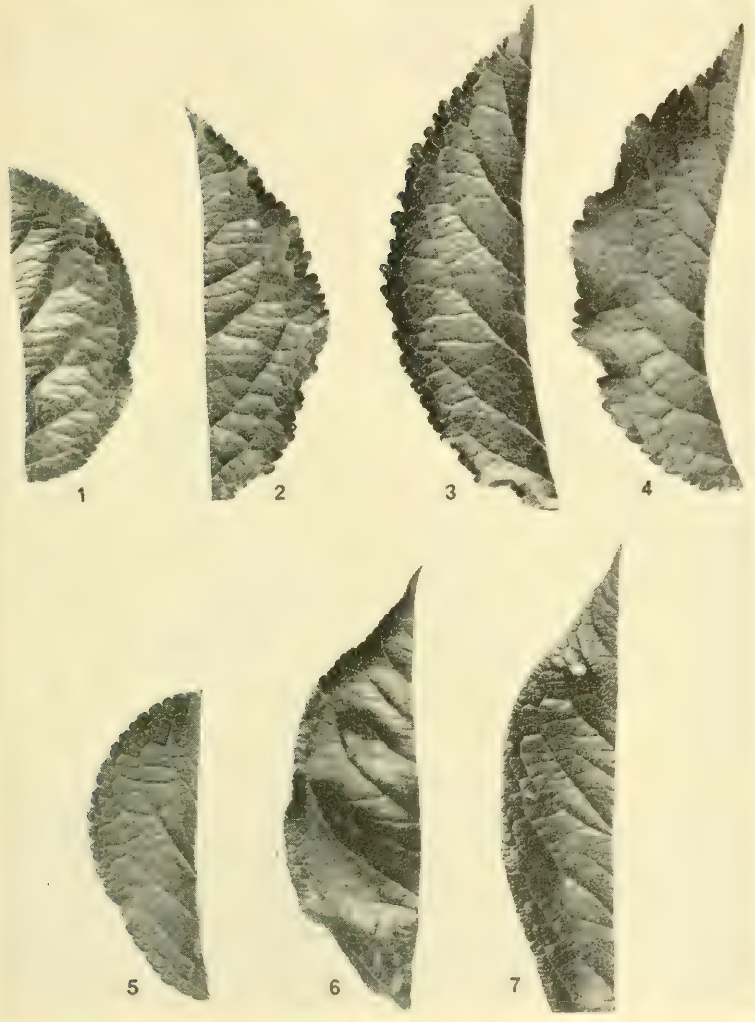


Figure 11. Serrations.

1. **MONARCH** — fine, rather shallow, double, dull serrate, regular;
2. **GERMAN PRUNE** — rather fine, medium in depth, dull serrate;
3. **ITALIAN PRUNE** — medium in size, rather deep, double to triple, dull serrate to crenate;
4. **STANLEY** — coarse, rather deep, double, dull serrate, irregular;
5. **AMERICAN MIRABELLE** — coarse, moderately shallow, crenate, somewhat irregular;

ABUNDANCE — fine, shallow, double, crenate, regular;
BURBANK — fine, very shallow, double, crenate, irregular, indistinct.

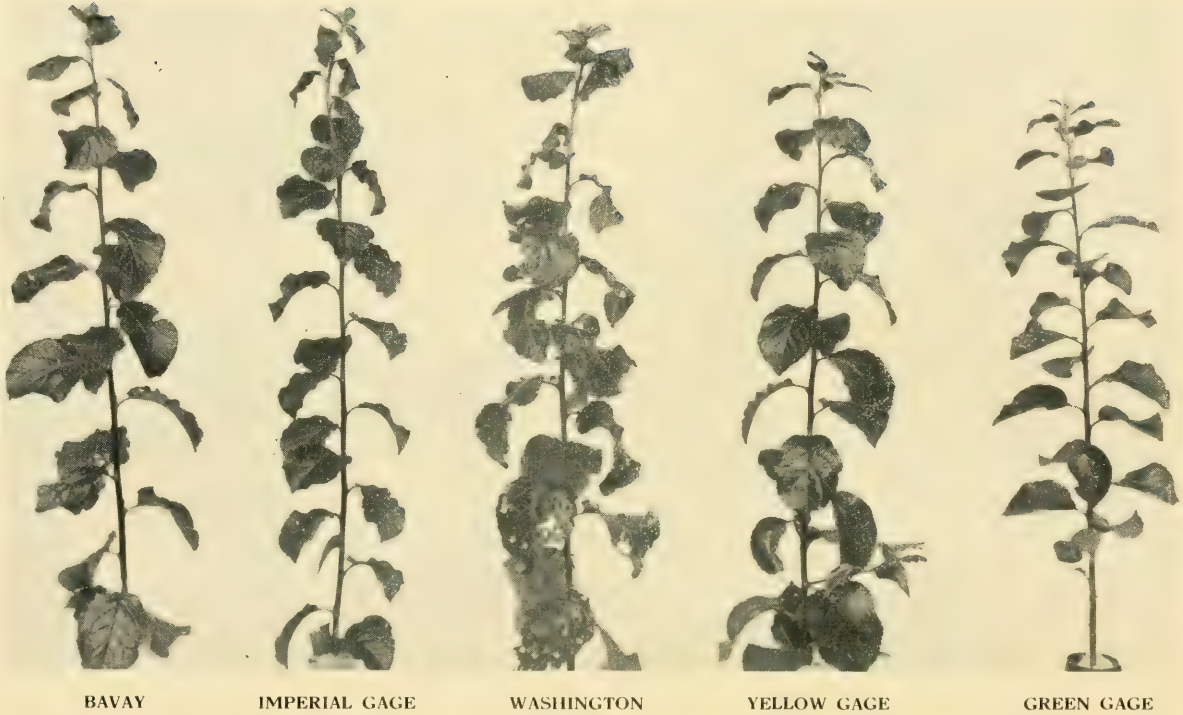

BAVAY
IMPERIAL GAGE
WASHINGTON
YELLOW GAGE
GREEN GAGE

Figure 12

Prominent Characteristics

Bavay (commonly grown under the name **Reine Claude**). Leaf large, roundish, flattish, drooping; leaf tip short acute, twisted; margin somewhat coarsely waved; serrations crenate; surface mostly smooth, medium green, rather glossy; glands usually 2, rather small, yellowish, close to or on the blade; growing tips often purplish tinged; shoots mostly purplish, glabrous.

Imperial Gage. Leaf moderately small, round-oval, broad U-folded, often saucer-folded near growing tip, often reflexed; margin medium-waved; surface bullate, mostly dull, medium grayish green; petiole short; glands 2, green, globose, with depressed centers; growing tips green; shoot pubescence mostly light.

Washington. Leaf larger than in most varieties, round-oval, mostly flat, drooping, often twisted; leaf tip very short, twisted; surface smooth to slightly rugose, semi-glossy, lightly pubescent, distinctive rather light yellowish green; petiole short, very thick; glands 0-2, on the blade, very small; shoots often pinkish; pubescence light to medium, very short; lenticels few; tree looks "leafy."

Yellow Gage. Leaf roundish-oval, typically broad U-folded (sometimes leaf edges turn up), somewhat drooping; margin medium-waved; serrations shallow; surface mostly smooth, semi-glossy, slightly pubescent; glands 1-2, close to or on the blade; growing tips reddish; two-year bark light to medium brown, lenticels fairly conspicuous; one-year tree considerably branched.

Green Gage. Leaf rather small, typically medium U-folded; leaf tip very short and sharp; margin medium-waved; serrations fine; surface mostly smooth, semi-glossy to dull, dark green; glands 1-2, close to the blade, small; growing tips often bronzed; shoot pubescence light and very short; one-year tree considerably branched.

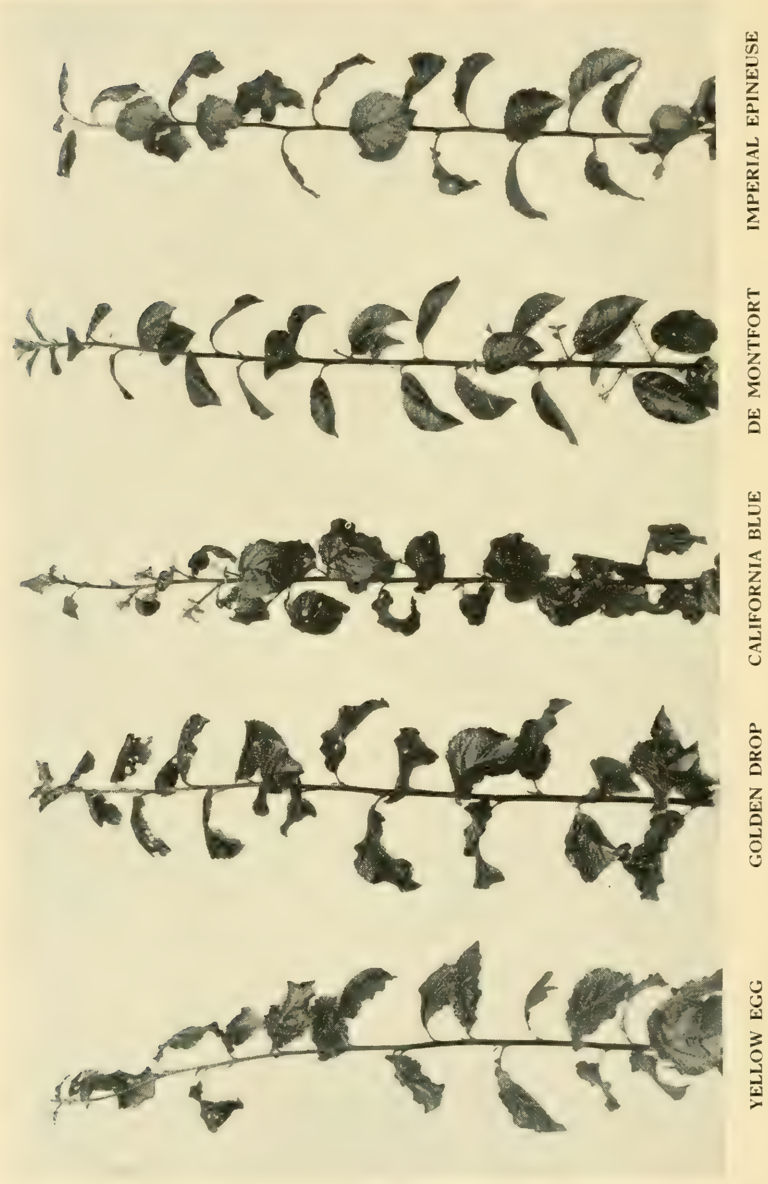

YELLOW EGG
GOLDEN DROP
CALIFORNIA BLUE
DE MONTFORT
IMPERIAL EPINEUSE

Figure 13

Prominent Characteristics

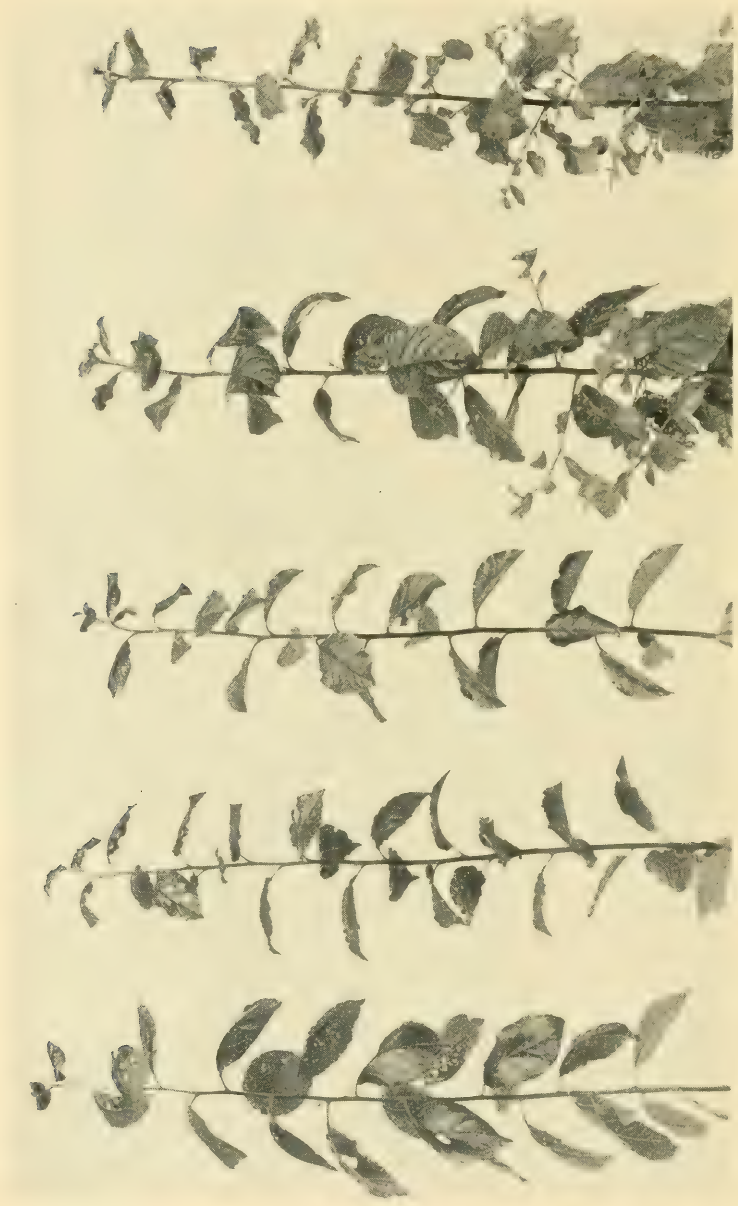
Yellow Egg. Leaf moderately large, mostly flat, roundish-oval, drooping; margin typically medium-waved; surface rugose, lightly pubescent, rather light yellowish green; growing tips light green to reddish tinged; glands 1-2, small, usually on the blade; shoots dull pink, very slightly pubescent though hairs may be rather long; two-year bark light brown.

Golden Drop.—Leaf flat to broad U-folded or saucer-folded, often reflexed; leaf tip twisted; margin mostly coarsely waved; surface semi-glossy, dark green; growing tips reddish; glands 2, small, very close to or on the blade; shoots, often purplish; pubescence none to trace.

California Blue.—Leaf moderately small, mostly flat, very drooping, much twisted; margin medium to finely waved; surface rugose, dark green, rather dull; growing tips green to reddish tinged; glands 2, very large, green, fairly well down on the petiole; shoot pubescence very light.

De Montfort.—Leaf rather small, especially near shoot tips, flat to "boat-shaped"; margin mostly even; surface smooth, dull, medium yellowish green; some likeness to apple leaf; petiole short; glands 0-2, close to or on the blade; shoots heavily pubescent, purplish.

Imperial Epineuse.—Leaf rather small, oval to obovate, mostly medium U-folded; surface smooth to bullate, rather light yellowish green; serrations fine, deep; petiole wide-angled, short, slender, red; glands 2, yellow; shoots pink to purple; pubescence none to trace; older shoots dark purple, glaucous; zigzag.



ITALIAN PRUNE
GERMAN PRUNE
AGEN
PACIFIC
YAKIMA

Figure 14

Prominent Characteristics

Italian Prune (Fellenburg). Leaf large, long-oval to obovate, saucer-folded to reverse keel-folded, drooping; margin moderately finely waved; serrations often triple; surface semi-glossy, dark yellowish green, slightly pubescent with the rather long hairs confined mostly to midrib and large veins; glands 2, often stalked, slightly reniform; growing tips red; shoots glabrous.

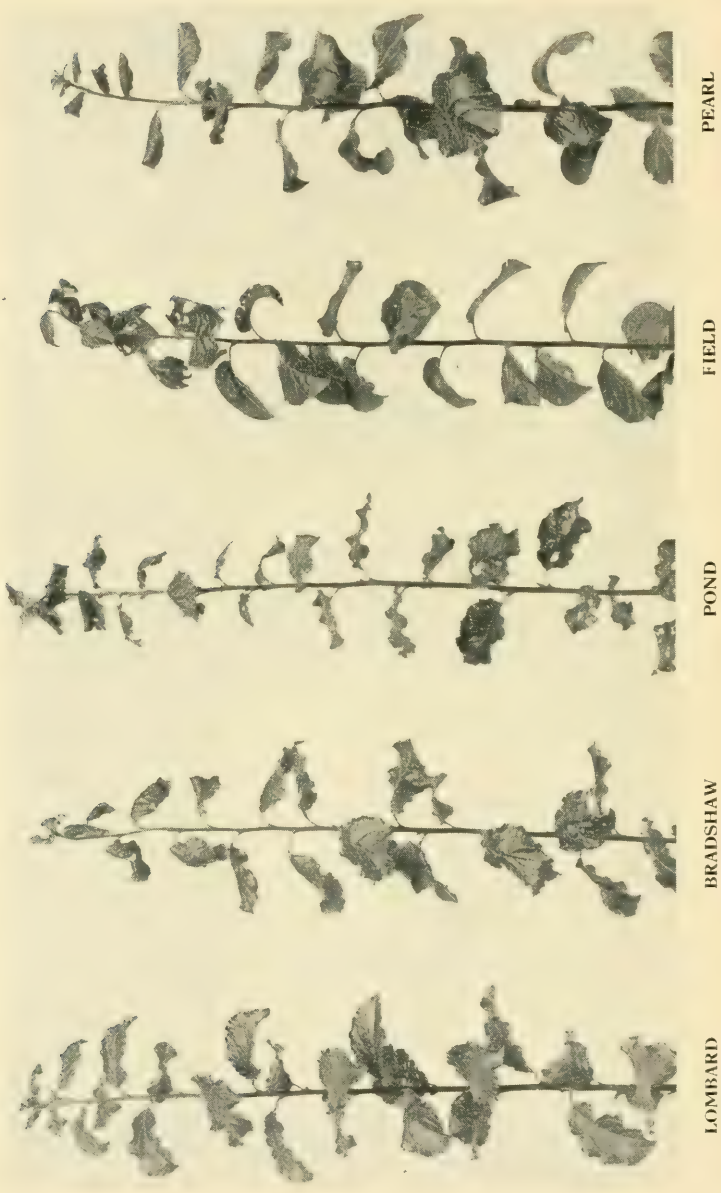
German Prune. Leaf small to medium, mostly flat; margin finely waved; serrations fairly deep; surface lightly to moderately pubescent (feels rough to the touch); petiole often upcurving, short, green; glands 2, on the blade, very small; growing tips reddish; shoots mostly green, rather slender, glabrous; two-year bark reddish brown.

Agen. Leaf rather small, medium to narrow U-folded, sometimes "rolled"; leaf tip short acute; surface mostly smooth, dull, rather light yellowish green; serrations shallow, regular; petiole wide-angled, short, reddish; glands 2, very small, often stalked; growing tips reddish; shoots reddish to purplish; pubescence none to trace; two-year bark light brown.

Pacific. Leaf moderately large, somewhat drooping, flat to broad U-folded; leaf tip often twisted; surface slightly rugose, rather dull, very slightly pubescent; serrations medium in size, regular; glands 2, well down on the petiole; shoots mostly greenish, glabrous; lenticels fairly conspicuous.

Yakima. Leaf medium in size, flat; margin coarsely waved; leaf tip twisted, often slightly upcurved; surface moderately rugose, lightly pubescent, gray green, dull; glands 2-3, very close to the blade, large, often stalked, green, irregular reniform; growing tips often reddish; shoots often purplish, glabrous.

FIGURE 15


PEARL
FIELD
POND
BRADSHAW
LOMBARD

Prominent Characteristics

Lombard.– Leaf medium in size to moderately large, with reflexed and twisted tip; margin rather finely waved; surface semi-glossy, dark green, bullate; growing tips mostly green; glands 1-2, close to or on the blade; shoots purplish, glabrous; lenticels conspicuous; two-year bark moderately light brown.

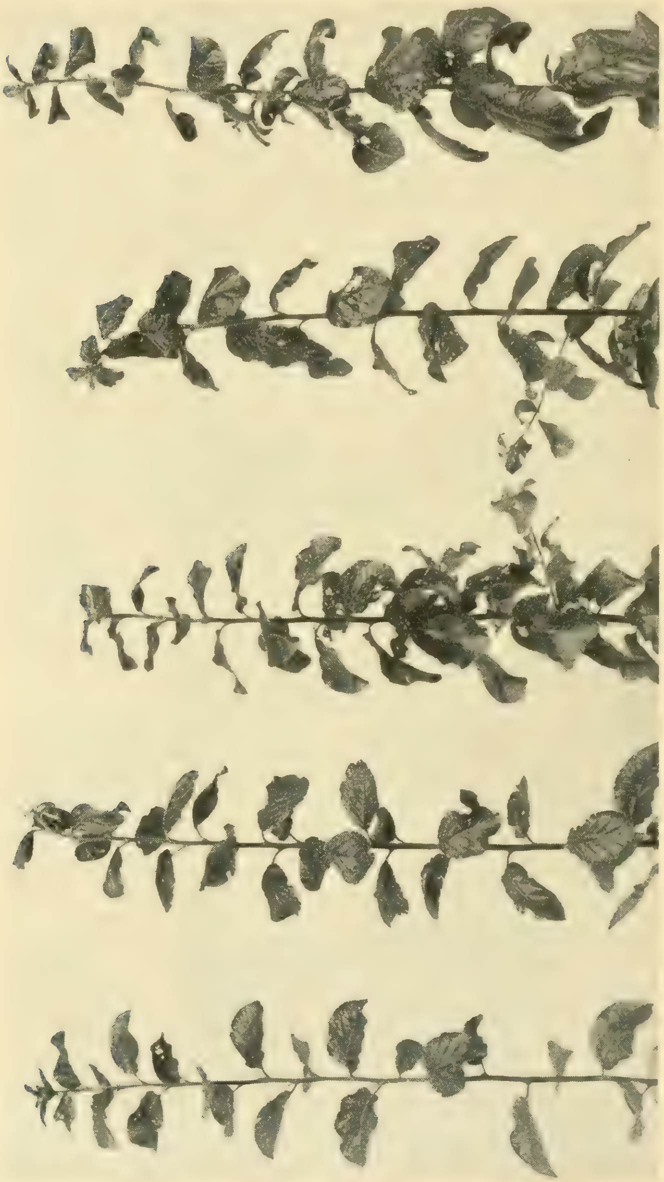
Bradshaw.– Leaf rather rigid, somewhat saucer-folded to reverse keel-folded, reflexed, much twisted; margin coarsely and finely waved; surface rugose and bullate, very lightly pubescent (rather long hairs); petiole long; glands 2, stalked; shoots often purplish and usually glabrous; lenticels conspicuous on older bark; growth habit upright.

Pond. Leaf rather small, mostly flat; leaf tip blunt acute, twisted; margin finely and medium-waved, sometimes coarsely waved; serrations coarse; surface rugose and bullate, mostly dull, lightly pubescent; growing tips mostly light green; shoots greenish to dull reddish tinged or purplish, glabrous.

Field. Leaf large, roundish, mostly flat; surface smooth to slightly rugose, dull, medium green; serrations shallow, regular; petiole thick, red; glands 0-2, small, on the blade; growing tips red; shoots purplish, rather heavily pubescent.

Pearl.—Leaf roundish, mostly flat, drooping; leaf tip much reflexed; margin medium-waved; surface very bullate, glossy, slightly pubescent, rather dark yellowish green; glands 2, on the petiole, greenish to reddish; growing tips very red; young leaves often reddish; shoot pubescence light, very short.

Figure 16


MONARCH
ARCH DUKE
SHIPPER'S PRIDE
GUEH
GLASS

Prominent Characteristics

Monarch. Leaf moderately small, roundish, broad U-folded, often "cupped-up" near growing tip, erect; leaf tip mucronate, twisted; surface fine, moderately rugose, semi-glossy, slightly pubescent, medium green; serrations fine, rather sharp, regular; petiole very short; glands 1-2, small, close to the blade; growing tips reddish; shoot pubescence heavy.

Arch Duke. Leaf usually flattish; leaf tip short acute to mucronate; surface moderately bullate, rather dull, slightly pubescent, medium green; glands 2, often reniform; growing tips mostly green; shoots purplish, very pubescent.

Shipper's Pride. Leaf round-oval, broad U-folded to saucer-folded; apex very broad; leaf tip often obtuse; margin coarsely waved; surface slightly rugose, moderately dull, lightly pubescent, medium green with occasional mottling; petiole extremely short, thick, green; glands 1-2, on the blade, small; growing tips mostly reddish; shoots very heavily pubescent; internodes short, making shoots appear leafy.

Gueii. – Leaf rather large, roundish-oval, mostly flat; surface somewhat rugose, moderately dull, medium green; lenticels few, very small; petiole reddish; glands 1-2, close to or on the blade, small; growing tips reddish tinged to light reddish; shoots pinkish, rather stout, heavily pubescent for entire length.

Glass. Leaf large, often flat but usually reverse saucer-folded, drooping; leaf tip small, obtuse, reflexed; surface somewhat rugose and bullate, very glossy, dark green; petiole short, thick, green; glands 2, close to or on the blade; growing tips reddish tinged to moderately reddish; shoots purplish, heavily pubescent; internodes short, making shoots appear leafy.

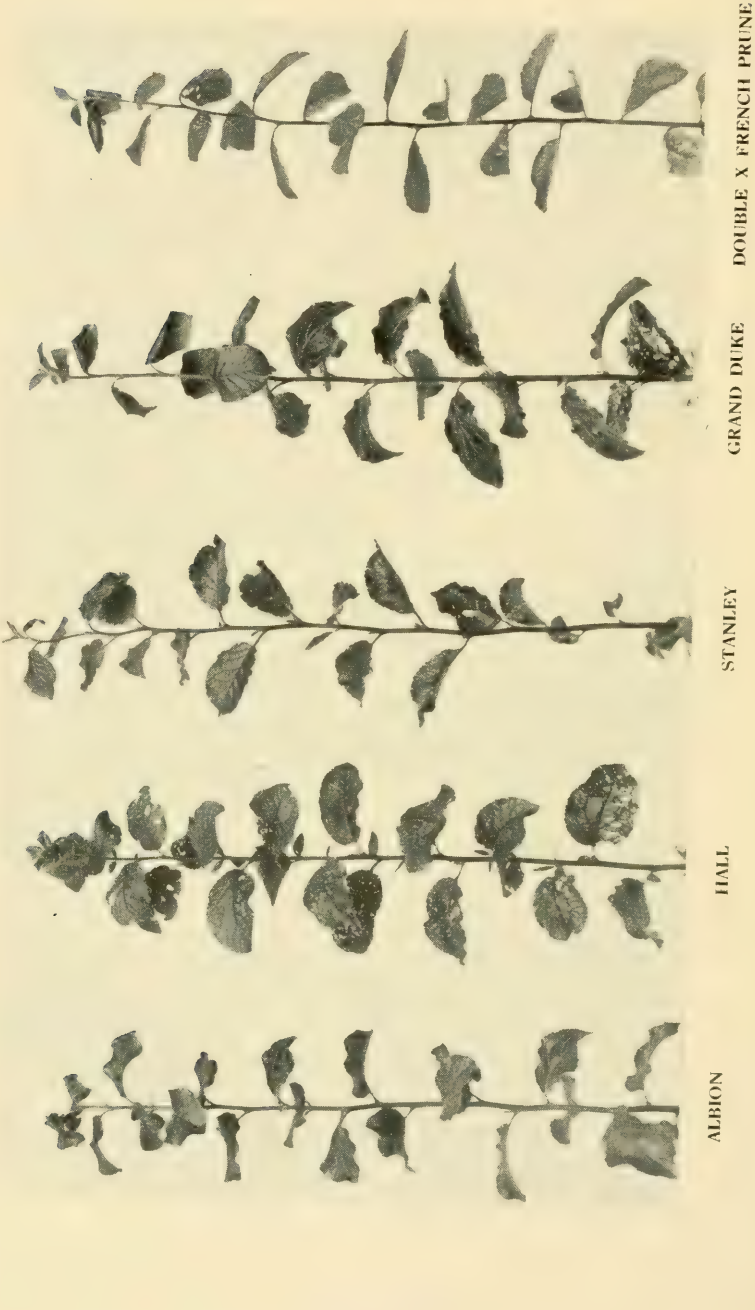

ALBION
HALL
STANLEY
GRAND DUKE
DOUBLE X FRENCH PRUNE

Figure 17

Prominent Characteristics

Albion.– Leaf roundish-oval, flat to broad V-folded, moderately erect; leaf tip acute, often twisted; margin coarsely waved; surface fine, mostly smooth, veiny, dull, rather dark green; glands 2, usually close to the blade; growing tips reddish tinged to reddish; shoots green to brownish, lightly pubescent; two-year bark rather light brown.

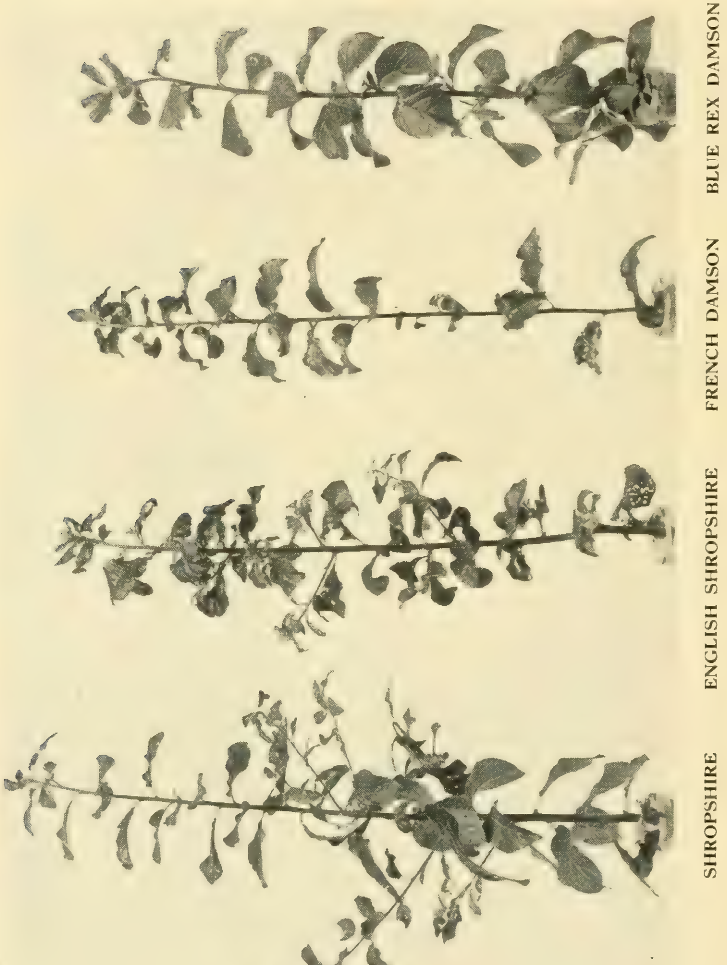
Hall.– Leaf oval, mostly flat, often somewhat drooping; leaf tip broad acute, twisted, slightly reflexed; surface moderately rugose, dull, slightly pubescent, medium green; glands 1-2, close to or on the blade; growing tips reddish; shoot lenticels numerous, pubescence none to a trace; two-year bark dark brown.

Stanley.– Leaf small to medium, oval to obovate, mostly rather narrow U-folded, erect; margin typically medium-waved; serrations coarse; surface somewhat bullate and often rugose especially along the midrib, mostly dull, medium yellowish green; petiole reddish; glands 2, on the petiole; growing tips reddish tinged to reddish; shoots purplish, pubescence none to a trace; one-year bark purple.

Grand Duke. Leaf rather large, flat to saucer-folded, often more folded near growing tip; margin finely waved; serrations somewhat coarse; surface mostly smooth, semi-glossy, rather dark green; petiole green to reddish tinged, moderately long; glands 2, close to or on the blade, small; growing tips reddish tinged to reddish; shoots green to purplish tinged, often blotchy, glabrous.

Double X French Prune. Leaf rather small, long-oval, flat to typically narrow U-folded, sometimes reverse keel-folded; leaf tip very short; surface mostly dull, moderately pubescent on older leaves; petiole reddish; glands 2, well down on the petiole, usually very small, leafy-stalked; growing tips reddish; young shoots reddish tinged; shoot pubescence none to trace.

Figure 18


SHROPSHIRE
ENGLISH SHROPSHIRE
FRENCH DAMSON
BLUE REX DAMSON

Prominent Characteristics

Shropshire. Leaf usually small, oval to long-oval; leaf tip sharp-pointed; surface slightly rugose, dull, rather light green; serrations fine, medium deep, rather sharp; glands 1-2, often on the blade; growing tips reddish tinged; shoot pubescence medium or above; branchy with many spur growths; two-year bark medium brown.

English Shropshire. Leaf usually small, oval to elliptic, twisted; leaf tip short, reflexed, round-pointed; margin rather coarsely waved; surface rugose, moderately dull, medium green; glands 1-2, close to the blade; growing tips reddish tinged; shoot pubescence light to medium; branchy; two-year bark rather dark brown.

French Damson. Leaf usually small, oval; leaf tip twisted, reflexed; margin considerably finely waved, sometimes medium-waved; surface slightly bullate, semi-glossy to dull, dark green; petiole somewhat upcurving; glands 1-2; growing tips dark red; shoot pubescence light; lenticels small, whitish; branchy; two-year bark dark brown.

Blue Rex Damson. Leaf usually moderately small, roundish oval; leaf tip very short, small; margin mostly coarsely waved; serrations fine, shallow, crenate; surface rather fine, mostly smooth, dull, dark green; glands 0-2, often on the blade; growing tips reddish tinged; shoot pubescence light; moderately branchy; shoots apt to be purple tinged.

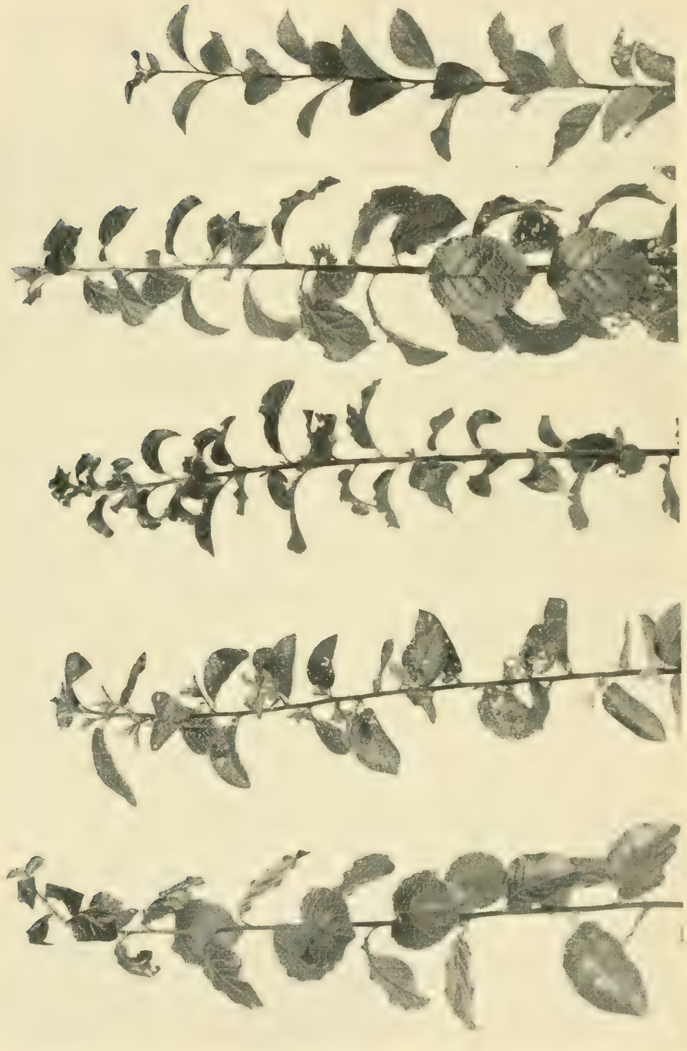

PRESIDENT
EARLY LAXTON
SANNOIS
GENERAL HAND
AMERICAN MIRABELLE

Figure 19

Prominent Characteristics

President. Leaf moderately large, flat to broad U-folded or saucer-folded, somewhat drooping; margin coarsely waved; serrations very fine, shallow, sharp, regular; surface mostly smooth, very glossy; glands 0-2, very small, on the blade; shoots green to purplish, glabrous, glaucous.

Early Laxton. Leaf rather small, roundish-oval, saucer-folded, rather erect; margin even; serrations very shallow, crenate; surface smooth, very dull, heavily pubescent, light green, "apple-like"; glands 1-2, very close to or on the blade; growing tips light green; shoots light purplish, heavily pubescent.

Sannois.– Leaf usually small, medium U-folded, thick textured, reflexed; margin medium-waved; serrations rather deep; surface somewhat rugose and bullate, semi-glossy; petiole short, thick, green; glands 1-2, close to or on the blade; shoots often pinkish tinged, with none to a trace of pubescence.

General Hand. Leaf long oval to obovate, broad U-folded, drooping; margin medium to finely waved; surface moderately rugose, dull, veiny; glands 2, close to or on the blade, often stalked, yellowish; growing tips usually green; shoots green to purplish, glabrous; lenticels very few, small; two-year bark grayish brown, netted scarfskin.

American Mirabelle. Leaf small, medium U-folded, erect; leaf tip short acute; surface bullate, dull; petiole often upturned, reddish; glands 2, often moderately well down on the petiole; growing tips reddish tinged; shoots purplish, pubescence very light; two-year bark purplish brown.

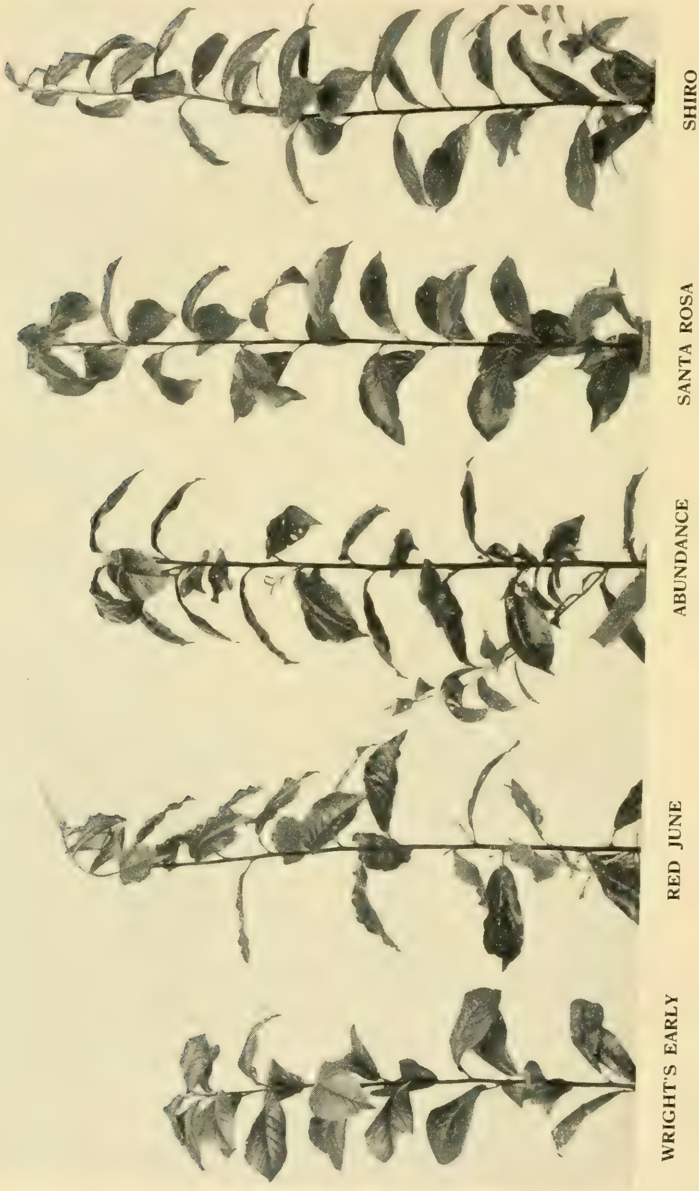

SHIRO
SANTA ROSA
ABUNDANCE
RED JUNE
WRIGHT'S EARLY

Figure 20

Prominent Characteristics

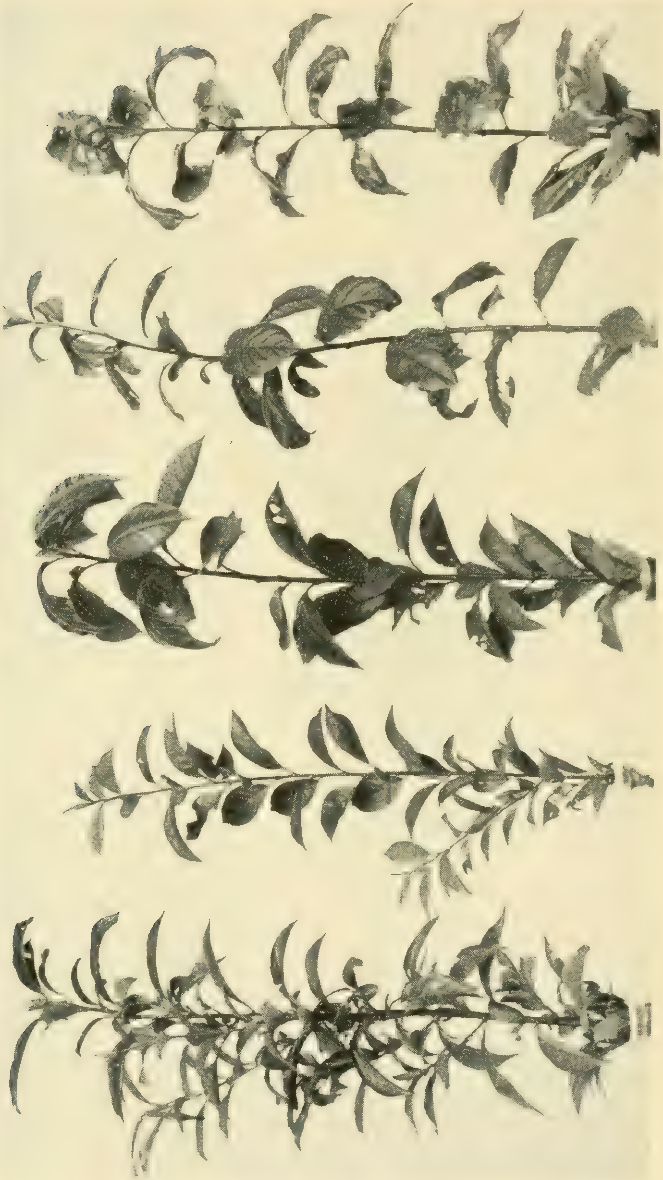
Wright's Early.– Leaf medium in size, obovate, mostly flattish, sometimes reverse saucer-folded, drooping; leaf tip small, reflexed; margin even; serrations very shallow; surface rugose, dull; glands 2-4 (more often 2), mixed, scattered; growing tips green; shoots dull yellowish green; lenticels rather small, moderately numerous; one year bark with rough epidermis; somewhat similar to Burbank.

Red June. Leaf elliptic, often medium U-folded; leaf tip acuminate, twisted; margin coarsely waved; surface somewhat rugose, semi-glossy, rather dark yellowish green; petiole reddish; glands 2-4, close to the blade, moderately large, often reniform; shoots reddish to red; lenticels numerous, raised, conspicuous; coarse scarfskin on one-year bark; foliage colors to red rather early in fall.

Abundance. Leaf oval to obovate, mostly flat to slightly reverse saucer-folded; leaf tip somewhat acuminate; surface mostly smooth, semi-glossy; glands 2-4, scattered, mixed; growing tips green; shoots reddish tinged; two-year bark dark brown.

Santa Rosa. Leaf rather small, long-oval to obovate, rather broad U-folded, erect; leaf tip often twisted; surface mostly smooth, fine, dull, prominent light greenish veins; glands 2, close to or on the blade, small, reniform; growing tips light green; shoots green to dull reddish tinged; lenticels very numerous; fine scarfskin on one-year bark.

Shiro. Leaf elliptic to obovate, broad V-folded; leaf tip reflexed; margin even; surface somewhat rugose, semi-glossy to dull; petiole reddish; glands 2-5, very small, leafy-stalked, often scattered; growing tips reddish tinged to reddish; shoots greenish to dull purplish.



ELEPHANT HEART
BURBANK
FORMOSA
BEAUTY
WICKSON

Figure 21

Prominent Characteristics

Wickson.—Leaf small, narrow elliptic, medium U-folded, midrib often reflexed; leaf tip acuminate; margin coarsely waved; surface smooth, almost semi-glossy; petiole upcurving; glands 2-4, usually close to the blade, yellowish; growing tips usually green; shoots green; lenticels few; one-year bark greenish, fine netted scarfskin; two-year growth habit very upright.

Beauty.– Leaf rather small, mostly broad V-folded; surface smooth, with short hairs or bristles (sometimes resembling pimples) which give a gritty or rough feeling, dull; serrations fairly distinct for this type of plum; glands usually 2-4, slightly stalked, scattered; one-year bark green with fine netted epidermis.

Formosa. Leaf large, obovate, broad U-folded or reverse keel-folded; leaf tip acuminate; surface slightly rugose, semi-glossy to dull; glands many, scattered; growing tips reddish tinged to reddish; shoots reddish; two-year bark light brown, many lenticels, rough epidermis.

Burbank.– Leaf large, long-obovate, broad U-folded to reverse saucer-folded, often drooping; leaf tip reflexed; margin even; surface slightly rugose, dull; glands 2-6, scattered, reniform; growing tips mostly green; shoots light brownish green; lenticels numerous, raised, conspicuous; epidermis coarse broken for full length of the shoots.

Elephant Heart. Leaf oval, flat to reverse saucer-folded; leaf tip acuminate, twisted, reflexed; margin coarsely waved; surface fine, slightly rugose, uneven, rather glossy, waxy, light yellowish mottled green; petiole reddish; glands 3-6, often well down on the petiole, rather large, reniform, yellow; growing tips yellowish green; shoots mostly dull yellowish green; lenticels few, small, inconspicuous.

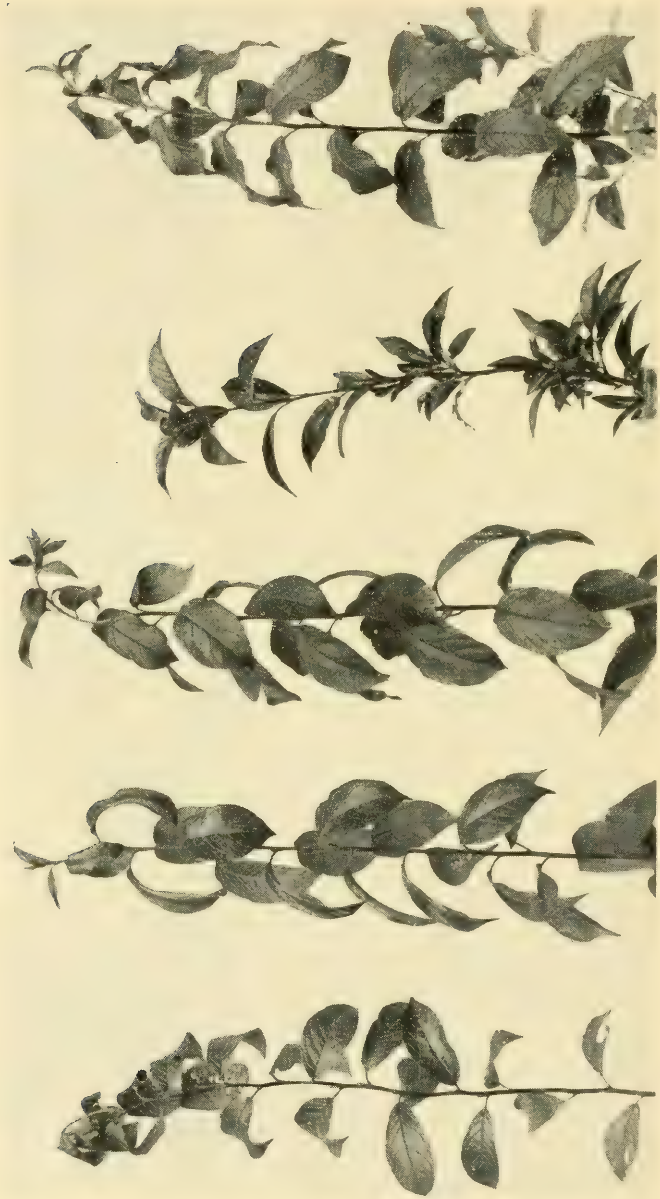

ELLIOT
SUPERIOR
UNDERWOOD
MONITOR
EMBER

Figure 22

Prominent Characteristics

Ember. Leaf elliptic to long-obovate mostly flat; leaf tip acute, often reflexed; surface somewhat bullate, semi-glossy to dull; petiole reddish; glands 3-6, scattered; growing tips reddish tinged to reddish; shoots often light reddish; lenticels many, rather small; growth habit spreading.

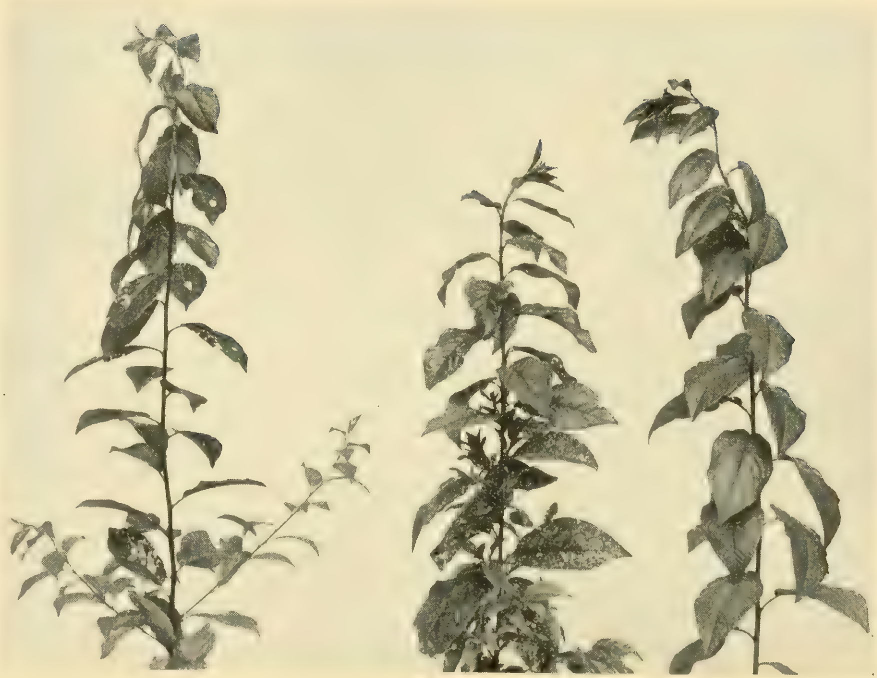
Monitor.– Leaf large, flat to reverse saucer-folded; leaf tip acuminate; margin even; surface smooth, principal veins depressed, glossy; petiole dull red; glands 2, close to the blade, moderately large, reniform, often sloughed off and inconspicuous; growing tips dull reddish; shoots greenish to dull purplish tinged; lenticels numerous, distinctly raised, conspicuous.

Underwood.– Leaf large, oval, flat to saucer-folded, drooping; leaf tip acute, twisted; margin even; surface mostly smooth, fine, dull; petiole red; glands 2-4, scattered, small, yellow, globose; growing tips red; shoots often dull reddish; lenticels very small, inconspicuous.

Superior.—Leaf elliptic, flat to broad V-folded; leaf tip acuminate; margin even; surface mostly smooth, dull; petiole moderately narrow-angled, green; glands 2-3; growing tips light green to reddish tinged; shoots green; lenticels few. (The picture gives the impression of poor vigor, which is not typical.)

Elliot.—Leaf rather large, broad elliptic, mostly flat; margin somewhat coarsely waved; surface somewhat rugose to bullate, mostly dull; glands 2-5, scattered, somewhat stalked; growing tips reddish tinged; shoots reddish tinged; lenticels numerous, small, raised; growth habit very spreading.

Figure 23



METHLEY RED COAT PIPESTONE

Prominent Characteristics

Methley.—Leaf moderately small, mostly flat; leaf tip long acute; margin mostly even; serrations fine, regular; surface somewhat rugose; petiole dull reddish; glands 2-4, small, on the petiole; growing tips reddish tinged to somewhat reddish; shoots reddish, glabrous.

Red Coat.— Leaf oval to broad elliptic, mostly flat; margin slightly coarsely waved; surface rugose, finely pubescent (moderately bristly), dull, somewhat mottled light yellowish green; glands 2, moderately well down on the petiole, rather large; growing tips reddish; shoot lenticels numerous; dwarfish growth.

Pipestone.— Leaf large, oval to broad elliptic, flat to reverse saucer-folded; surface somewhat rugose, mostly dull, lightly pubescent (moderately bristly); serrations fine, double to triple; petiole reddish; glands usually 4 with 2 well down on the petiole, rather large, often brownish; growing tips reddish; shoots dull green.

Variety Keys

A variety key is an arbitrary classification of varieties based on a few selected characteristics and arranged in such a way that a variety may be identified rather quickly by following through the key. However, such a key is not infallible since it is based on characteristics that exhibit natural variation, as for example, color and size. Nevertheless, if used with discretion, a good key may often be useful in variety identification. The following two keys include the varieties considered in this bulletin. Since the varieties naturally group themselves into two categories, two keys are given instead of one single key. Nursery trees of the European and Damson plums are, in general, easily distinguished from the Japanese and Japanese-American hybrid varieties by the coarser leaf texture of the former more U-folding in contrast to V-folding, more deeply serrated margins, less acuminate leaf tips, fewer glands, fewer and less conspicuous lenticels and scarfskin, and more purple color on shoots and bark. None of the Japanese or hybrid plums have pubescent shoots, while many European varieties are characteristically pubescent.

These keys are based on plant characters of healthy and vigorous one- and two-year-old nursery trees as they appeared in late June and July. In general, though the characters as described may be affected by a changed environment due to location or season, varieties maintain their relative order for each character so that a key may be useful over a wide range of growing conditions. Alderman and Shoemaker (1) have made a key for 35 varieties commonly grown in the Upper Mississippi Valley. However, except in a very few cases, the varieties are not those discussed in this bulletin and consequently the identifying characters used in the respective keys are somewhat dissimilar.

KEY TO EUROPEAN AND DAMSON VARIETIES

A Shoots glabrous or nearly so
 B Growing tips prevailingly green
  C Leaf surface semi-glossy
   D Leaf color medium green, leaf rigid, much twisted *9 Bradshaw
   DD Leaf color dark green, lenticels fairly conspicuous 32 Lombard
  CC Leaf surface mostly dull
   D Leaf color light yellowish green.............. 56 Yellow Egg
   DD Leaf color medium green
    E Leaf rather small, round-oval, twisted 39 Pond
    EE Leaf medium in size, long-oval to obovate......................... 21 General Hand
 BB Growing tips usually reddish tinged, occasionally reddish
  C Leaf surface semi-glossy to glossy
   D Leaf margin finely waved, rather coarse serrations.................................. 25 Grand Duke
   DD Leaf margin medium to coarsely waved
    E Leaf large, flat to broad U-folded or saucer-folded
     F Serrations very fine, serrate; leaf very glossy........................... 40 President
     FF Serrations medium in size, crenate.... 6 Bavay
    EE Leaf moderately small, medium U-folded . 43 Sannois
  CC Leaf surface mostly dull
   D Leaf medium to narrow U-folded
    E Leaf rather light yellowish green, serrations rather fine......................... 29 Imperial Epineuse
    EE Leaf medium yellowish green, serrations rather coarse .... 49 Stanley

DD Leaf mostly flattish
E Glands 2-3, large, very close to the blade . . . . 55 Yakima
EE Glands 2, medium in size, well down on the petiole . . . . 36 Pacific
BBB Growing tips reddish to red
C Leaf surface semi-glossy
D Leaf long-oval to obovate, large, often reverse keel-folded; glands medium in size; serrations often triple, rather deep, dull serrate to crenate 31 Italian Prune
DD Leaf oval, medium or above in size, dark green; glands small; serrations medium deep, crenate 24 Golden Drop
DDD Leaf roundish-oval, medium in size, medium green; serrations rather fine, dull serrate . . . . 57 Yellow Gage
CC Leaf surface mostly dull, occasionally somewhat semi-glossy
D Glands well down on the petiole . . . . 13 Double X French Prune
DD Glands usually on the petiole but close to the blade
E Leaves mostly flat, rugose . . . . 28 Hall
EE Leaves medium to narrow U-folded, mostly smooth . . . . 2 Agen
DDD Glands on the blade, leaf margin finely waved . 22 German Prune
AA Shoots pubescent
B Growing tips prevailingly green
C Glands large, fairly well down on the petiole . . . . 11 California Blue
CC Glands small to medium, rather close to the blade
D Upper leaf surface heavily pubescent . . . . 14 Early Laxton
DD Upper leaf surface not pubescent or only slightly so
E Shoot pubescence heavy . . . . 5 Arch Duke
EE Shoot pubescence mostly light . . . . 30 Imperial Gage
BB Growing tips usually reddish tinged, occasionally reddish
C Leaf medium to large, roundish oval
D Glands on the blade
E Shoot pubescence light to medium . . . . 52 Washington
EE Shoot pubescence very heavy . . . . 45 Shipper's Pride
DD Glands usually close to but sometimes on the blade
E Leaf surface mostly dull
F Shoot pubescence light . . . . 3 Albion
FF Shoot pubescence rather heavy . . . . 27 Gueii
EE Leaf surface very glossy, shoot pubescence heavy . . . . 23 Glass
CC Leaf usually rather small
D Shoot pubescence heavy, leaf somewhat "apple-like" . . . . 12 De Montfort
DD Shoot pubescence light to medium
E Leaf surface rugose, leaf tip dull-pointed . . 48 Shropshire (English)
EE Leaf surface slightly rugose, leaf tip sharp-pointed . . . . 47 Shropshire
DDD Shoot pubescence very light
E Leaf medium U-folded, serrations rather coarse . . . . 4 American Mirabelle
EE Leaf broad V-folded, serrations rather fine . 8 Blue Rex Damson
BBB Growing tips reddish to red
C Leaf surface semi-glossy or glossy
D Shoot pubescence heavy . . . . 34 Monarch
DD Shoot pubescence light, growing tips very red . . 37 Pearl
CC Leaf surface mostly dull
D Shoot pubescence moderately heavy . . . . 18 Field
DD Shoot pubescence light
E Tip leaves reddish, margin medium-waved 26 Green Gage
EE Tip leaves dark red, margin usually rather finely waved, lenticels whitish . . . . 20 French Damson

---

*For complete variety descriptions, see pages 43-51, and locate the desired varieties by the numbers as listed here.

KEY TO JAPANESE AND HYBRID VARIETIES

A Growing tips mostly green	
B Leaf margin even	
C Lenticels numerous, raised, conspicuous; leaf large, long-obovate	*10 Burbank
CC Lenticels moderately numerous, mostly flush; leaf medium to large, obovate	54 Wright's Early
BB Leaf margin coarsely waved	
C Leaf small to medium	
D Leaf narrow elliptic, smooth, almost semi-glossy	53 Wickson
DD Leaf oval to elliptic, smooth to slightly rugose, dull	44 Santa Rosa
CC Leaf medium or above in size	
D Leaf rather glossy and "waxy"; glands 3-6, large, often well down on the petiole	15 Elephant Heart
DD Leaf semi-glossy; glands 2-4, small to medium, scattered	1 Abundance
AA Growing tips reddish tinged, sometimes reddish	
B Leaf margin even	
C Leaf surface moderately rugose, semi-glossy to dull; petiole reddish	46 Shiro
CC Leaf surface smooth to slightly rugose, dull; petiole green	50 Superior
BB Leaf margin slightly coarsely waved	
C Glands somewhat down on the petiole, uniform in number	
D Glands 4, 2 well down on the petiole; young shoots dull green	38 Pipestone
DD Glands 2, fairly well down on the petiole; young shoots reddish tinged; dwarf grower	41 Red Coat
CC Glands scattered, variable in number	
D Glands very numerous	19 Formosa
DD Glands 2-6 in number	
E Lenticels numerous, raised	
F Leaf elliptic to long-obovate, flat to broad U-folded, semi-glossy to dull	17 Ember
FF Leaf broad elliptic, flat to broad V-folded to slightly reverse saucer-folded, dull	16 Elliot
EE Lenticels medium in number, flush	
F Leaf surface smooth but bristly to the touch; serrations distinct	7 Beauty
FF Leaf surface moderately rugose; serrations shallow	33 Methley
BBB Leaf margin coarsely waved; surface usually rugose, semi-glossy; lenticels numerous, raised, very conspicuous	42 Red June
AAA Growing tips reddish to red	
B Leaf rather glossy; glands 2, large, reniform; lenticels conspicuous	35 Monitor
BB Leaf dull; glands 2-4, small, globose; lenticels very small, not conspicuous	51 Underwood

---

* For complete variety descriptions, see pages 43-51, and locate the desired varieties by the numbers as listed here.

VARIETY DESCRIPTIONS

1. **Abundance.** Habit fairly upright, medium in height, medium stout; internodes rather short. Two-year bark rather dark brown; one-year bark reddish brown; young shoots reddish tinged; pubescence none; lenticels medium in number, small, flush, russet; growing tips green; young leaves moderately light green. Petiole medium-angled, short, medium thick, reddish tinged; glands 2-4, scattered, medium to small, globose and reniform, yellowish green. Leaf blade medium in size, oval to obovate, flat to slightly reverse saucer-folded; tip somewhat acuminate; margin slightly coarsely waved; surface slightly rugose, semi-glossy, light to medium yellowish green; serrations fine, shallow, double, crenate, rather regular.

2. **Agen.** Habit upright-spreading, moderately short, moderately slender; internodes short. Two-year bark light brown, lenticels conspicuous; one-year bark purplish to brown; young shoots reddish to purplish; pubescence none to a trace; lenticels medium in number, small, flush, russet; growing tips reddish; young leaves medium green. Petiole wide-angled, short, medium thick, reddish; glands 2, close to the blade, very small, often stalked, yellowish. Leaf blade rather small, oval, medium to narrow U-folded; tip short acute; margin slightly coarsely waved; surface mostly smooth, rather dull, rather light yellowish green; serrations moderately fine, shallow, double, dull serrate, regular.

3. **Albion.** Habit upright-spreading, moderately short, medium stout; internodes medium. Two-year bark moderately light brown; one-year bark greenish to light purplish to brown; young shoots green to slight purplish brown; pubescence light; lenticels few, small, flush, russet; growing tips reddish tinged to reddish; young leaves medium green. Petiole wide-angled, short, thick, reddish tinged; glands 2, close to the blade, medium in size, slightly stalked, greenish, with depressed centers. Leaf blade medium in size, roundish oval, flat to broad V-folded; tip acute, often twisted; margin coarsely waved; surface fine, veiny, very slightly rugose, dull, rather dark green; serrations medium in size, double, dull serrate, rather irregular.

4. **American Mirabelle.** Habit upright-spreading, rather short, medium stout; internodes medium. Two-year bark dark or purplish brown; one-year bark purple; young shoots purplish; pubescence very light; lenticels medium in number, small, flush, russet; growing tips reddish tinged; young leaves medium green. Petiole moderately wide-angled, upturned, medium in length, medium thick, reddish; glands 2, near the blade to fairly well down on the petiole, medium in size, greenish yellow, with depressed centers. Leaf blade small, oval to slightly obovate, medium U-folded; tip short acute; margin slightly coarsely waved; surface bullate, dull, medium green; serrations rather coarse, moderately shallow, crenate, somewhat irregular.

5. **Arch Duke.** Habit upright-spreading, medium in height, medium stout; internodes medium. Two-year bark medium brown; one-year bark green to purplish to brown; young shoots reddish tinged to purplish; pubescence rather heavy; lenticels numerous, small, flush, russet; growing tips green, or sometimes slightly reddish tinged; young leaves light to medium green. Petiole wide-angled, rather short, thick, reddish tinged; glands 2, close to the blade, moderately small, often reniform, green, with depressed centers. Leaf blade medium in size, oval, flat to saucer-folded; tip short acute to mucronate; margin slightly medium-waved; surface moderately bullate, somewhat semi-glossy to dull, slightly pubescent, medium green; serrations rather fine, moderately shallow, dull serrate, regular.

6. **Bavay** (commonly called **Reine Claude**). Habit upright-spreading, medium in height, rather stout; internodes rather short. Two-year bark medium brown; one-year bark green to purple to brown; young shoots slightly green to purplish; pubescence none; lenticels few, small, flush; growing tips purplish tinged to reddish; young leaves medium green. Petiole wide-angled, short, rather thick, tinged; glands 2, close to or on the blade, rather small, yellowish, with depressed centers. Leaf blade large, round-oval, broad U-folded or flat to slightly saucer-folded, drooping; tip short acute, twisted, slightly reflexed; margin somewhat coarsely-waved to medium-waved; surface smooth to slightly rugose and slightly bullate, rather glossy, medium green; serrations medium in size, moderately shallow, double, crenate, regular.

7. **Beauty.** Habit moderately upright, medium in height, rather slender; internodes rather short. Two-year bark gray brown; one-year bark green, with fine netted russet epidermis; young shoots green to reddish tinged; pubescence none; lenticels medium in number, small, flush, russet; growing tips reddish tinged; young leaves light yellowish green. Petiole medium-angled, rather short, slender, slightly reddish tinged; glands usually 2-4 (sometimes up to 6), close to the blade or scattered, rather small, slightly stalked, yellowish green. Leaf blade rather small, oval to elliptic, broad V-folded to slightly reverse saucer-folded; tip somewhat acuminate; margin slightly coarsely waved; surface smooth, hirsute (stiff hairs or bristles which give a gritty feeling), dull, moderately light green; serrations moderately fine, medium deep, double, moderately dull serrate, distinct, regular.

8. **Blue Rex Damson.** Habit spreading, medium in height, medium stout; internodes short. One-year bark purplish to brown; young shoots green to purple tinged; pubescence very light; lenticels very few, very small, flush, russet; growing tips reddish tinged; young leaves medium to dark green. Petiole rather wide-angled, very short, medium thick, green; glands 0-2, close to or on the blade, small, green. Leaf blade moderately small, roundish oval, broad V-folded, often drooping; tip small, often obtuse, often reflexed; margin coarsely waved; surface slightly rugose, rather dull, dark green; serrations rather fine, shallow, crenate, regular.

9. **Bradshaw.** Habit rather upright, tall, medium stout; internodes medium. Two-year bark moderately light brown with much netted scarfskin, lenticels conspicuous; one-year bark green to purplish to brown; young shoots reddish tinged to purplish, glaucous; pubescence none to very light and rather long; lenticels very few, small, flush, russet; growing tips green to slightly reddish tinged; young leaves medium green. Petiole wide-angled, rather long, medium thick, reddish tinged to reddish; glands 2, moderately close to the blade, medium in size, stalked, greenish, with slightly depressed centers. Leaf blade medium in size, oval, saucer-folded to reverse keel-folded, drooping, much twisted, rigid; tip acute, twisted; margin coarsely and finely waved; surface rugose and bullate, semi-glossy, very lightly pubescent, medium green; serrations medium in size, medium in depth, dull serrate, irregular.

10. **Burbank.** Habit spreading to drooping, tall, medium stout; internodes medium. Two-year bark medium brown; one-year bark medium brown with epidermis coarse broken for the full length of the shoots; young shoots green to light brownish; pubescence none; lenticels numerous, medium in size, raised, russet, conspicuous; growing tips green to very slightly reddish tinged; young leaves rather light yellowish green. Petiole wide-angled, short, rather thick, green; glands 2-6, scattered, medium in size, rather yellow, mostly reniform. Leaf blade moderately large, long obovate, broad U-folded to reverse saucer-folded, often drooping; tip long acute, reflexed; margin even; surface slightly rugose, dull, medium yellowish green; serrations fine, very shallow, double, crenate, irregular, indistinct.

11. **California Blue.** Habit upright-spreading, moderately tall, medium stout; internodes short. Two-year bark medium to rather dark brown; one-year bark purplish to brown; young shoots reddish tinged to purplish; pubescence very light; lenticels medium in number, small, flush, russet; growing tips green to reddish tinged; young leaves medium green. Petiole wide-angled, medium in length, thick, reddish tinged; glands 2, fairly well down on the petiole, large, often stalked, reniform, green, with depressed centers. Leaf blade small to medium, oval, flat to saucer-folded with some reverse keels and much twisting of midribs, very drooping; tip broad acute; margin medium-waved to finely waved; surface rugose, rather dull, dark green; serrations medium in size, moderately deep, crenate.

12. **De Montfort.** Habit upright-spreading, rather short, moderately slender; internodes moderately short. Two-year bark medium brown with fine scarfskin; one-year bark purplish to brown; young shoots green to purplish; pubescence heavy; lenticels few, small, flush, russet; growing tips reddish tinged; young leaves light green. Petiole wide-angled, short, rather thick, reddish tinged; glands 0-2, close to or on the blade, moderately small, yellowish green. Leaf blade rather small, oval, flat to medium U-folded or "boat-shaped"; tip acute; margin even to slightly coarsely waved; surface mostly smooth, dull, medium yellowish green; serrations rather fine, shallow, double, crenate, regular.

13. **Double X French Prune.** Habit upright, rather tall, medium stout; internodes rather short. Two-year bark medium brown; one-year bark purplish to brown; young shoots reddish tinged; pubescence none to trace; lenticels numerous, small, flush, russet; growing tips reddish; young leaves medium green. Petiole rather wide-angled, short, moderately thick, reddish; glands 2, often well down on the petiole, small, leafy-stalked, green. Leaf blade rather small, long-oval with tendency toward obovateness, flat to narrow U-folded or reverse keel-folded; tip very short, slightly mucronate; margin slightly coarsely waved; surface slightly bullate, slightly semi-glossy to dull, moderately pubescent on older leaves, rather light yellow green; serrations rather fine, rather shallow, double, dull serrate.

14. **Early Laxton.** Habit upright-spreading, rather short, medium stout; internodes moderately short. Two-year bark medium brown; one-year bark light purplish to light brown; young shoots reddish tinged to light purplish; pubescence rather heavy; lenticels medium in number, small, slightly raised, russet; growing tips light green; young leaves rather light yellowish green. Petiole moderately wide-angled, short, medium thick, green; glands 1-2, very close to or on the blade, rather small, green. Leaf blade rather small, roundish-oval, saucer-folded, upright; tip short acute; margin even; surface smooth, very dull, rather heavily pubescent, light green; serrations rather fine, very shallow, dull serrate to crenate.

15. **Elephant Heart.** Habit upright, rather tall, rather slender, internodes medium. Two-year bark brown, netted scarfskin; one-year bark green; young shoots yellowish green, sometimes slightly dull reddish tinged; pubescence none; lenticels few, small, flush, russet, inconspicuous; growing tips yellowish green; young leaves very light yellowish green. Petiole moderately wide-angled, medium in length, thick, reddish; glands 3-6, fairly well down on the petiole, rather large, reniform, yellow. Leaf blade medium or above in size, oval, flat to reverse saucer-folded; tip acuminate, slightly twisted, reflexed; margin coarsely waved; surface fine though slightly rugose, uneven, rather glossy, typically waxy, rather light yellowish green, mottled; serrations fine, shallow, double, dull serrate, rather irregular.

16. **Elliot.** Habit spreading to drooping, moderately tall, medium stout; internodes short. One-year bark reddish to greenish brown; young shoots reddish tinged; pubescence none; lenticels numerous, small, raised, russet; growing tips reddish tinged; young leaves medium green. Petiole moderately narrow-angled, short, medium thick, reddish tinged to reddish; glands 2-5, scattered, medium in size, somewhat stalked, yellowish. Leaf blade medium or above in size, broad elliptic, flat to broad V-folded or slightly reverse saucer-folded; tip short acute, slightly reflexed; margin slightly coarsely waved; surface slightly rugose to bullate, dull, medium green; serrations fine, shallow, double, crenate.

17. **Ember.** Habit spreading, rather tall, medium stout; internodes medium. Two-year bark reddish brown; one-year bark reddish to reddish brown; young shoots green to light reddish; pubescence none; lenticels rather numerous, moderately small, raised, russet; growing tips reddish tinged to reddish; young leaves medium green. Petiole medium-angled, short, medium thick, reddish; glands 3-6, scattered, medium in size, sometimes reniform, yellowish green. Leaf blade medium in size, elliptic to long-obovate, flat to broad U-folded; tip acute, slightly reflexed; margin slightly coarsely waved; surface slightly bullate, semi-glossy to dull, medium green; serrations fine, shallow, double, crenate, regular.

18. **Field.** Habit upright-spreading, moderately tall, medium stout; internodes medium. Two-year bark moderately dark grayish brown; one-year bark purple to slightly brown; young shoots purplish; pubescence moderately heavy; lenticels medium in number, small, flush, russet; growing tips reddish to red; young leaves medium yellowish green. Petiole wide-angled, medium in length, thick, red; glands 0-2, on the blade, small, often slightly stalked, green, with depressed centers. Leaf blade large, roundish oval, flat to slightly saucer-folded, drooping; tip broad acute; margin coarsely waved; surface slightly rugose, rather dull, medium green; serrations medium in size, moderately shallow, slightly double, dull serrate to crenate, regular.

19. **Formosa.** Habit upright-spreading, rather tall, medium stout; internodes moderately short. Two-year bark light brown, rough scarfskin; one-year bark purplish red to brown, coarse broken scarfskin; young shoots moderately reddish; pubescence none; lenticels rather numerous, small, slightly raised, russet; growing tips reddish tinged to moderately reddish; young leaves medium yellowish green. Petiole medium-angled, medium in length and thickness, reddish tinged to reddish; glands very numerous, scattered, moderately small, yellowish, roundish. Leaf blade moderately large, obovate, medium to broad U-folded with occasional reverse keel; tip acuminate; margin slightly coarsely waved; surface slightly rugose, moderately semi-glossy to dull, medium green; serrations rather fine, shallow, double, crenate, rather regular.

20. **French Damson.** Habit upright-spreading, medium in height, rather slender; internodes short. Two-year bark dark brown; one-year bark purple to brown; young shoots purplish; pubescence light; lenticels few, very small, flush, white; growing tips dark red; young leaves medium green, often bronzed. Petiole medium-angled, short, moderately slender, upcurving, reddish tinged; glands 1-2, close to or on the blade, small, greenish. Leaf blade small, oval, broad U- to V-folded; tip acute, twisted, reflexed; margin rather finely waved, sometimes medium-waved; surface slightly bullate, semi-glossy to dull, rather dark green; serrations rather fine, medium in depth, double, dull serrate to crenate.

21. **General Hand.** Habit upright-spreading, medium in height, moderately slender; internodes short. Two-year bark grayish brown, netted scarfskin; one-year bark purplish brown; young shoots green to purplish; pubescence none; lenticels very few, small, flush, russet; growing tips green to reddish tinged; young leaves medium green. Petiole wide-angled, rather short, medium thick, reddish tinged; glands 2, close to or on the blade, moderately small, often stalked, yellowish, round. Leaf blade medium in size, rather long-oval to obovate, broad U-folded, drooping; tip acute; margin medium to finely waved; surface moderately rugose, slightly bullate, dull, medium green; serrations fine, rather shallow, double, serrate to crenate, rather regular.

22. **German Prune.** Habit moderately upright, rather tall, moderately slender; internodes short. Two-year bark greenish brown to gray, some netted scarfskin; one-year bark green to slight purplish to light brown; young shoots green to slightly reddish tinged; pubescence none; lenticels few, small, flush, russet; growing tips reddish; young leaves medium green. Petiole rather wide-angled, often moderately upcurving, short, medium thick, green; glands 2, on the blade, very small, green. Leaf blade small to medium, oval, flat to saucer-folded; tip acute; margin finely waved; surface slightly rugose, slightly bullate, often moderately semi-glossy, sometimes dull, somewhat pubescent, moderately light green; serrations rather fine, medium in depth, moderately serrate.

23. **Glass.** Habit moderately upright, medium in height, moderately stout; internodes short; one-year bark purple; young shoots reddish tinged to purplish; pubescence heavy; lenticels few, small, flush, russet; growing tips reddish tinged to moderately reddish; young leaves medium to rather dark green. Petiole wide-angled, short, thick, green; glands 2, close to or on the blade, medium in size, slightly stalked, yellowish, with depressed centers. Leaf blade rather large, oval, flat to reverse saucer-folded, moderately drooping; tip small, obtuse, reflexed; margin slightly coarsely waved; surface moderately rugose, slightly bullate, very glossy, dark green; serrations rather fine, shallow, dull serrate, regular.

24. **Golden Drop.** Habit rather upright, rather tall, stout; internodes medium. Two-year bark medium to dark brown; one-year bark purple to brown; young shoots reddish tinged to purplish; pubescence none to trace; lenticels few, small, flush, russet; growing tips reddish; young leaves medium green. Petiole wide-angled, short, thick, slightly reddish tinged; glands 2, very close to or on the blade, small, stalked, green. Leaf blade medium or above in size, oval, flat to broad U-folded or saucer-folded, slightly drooping; tip acute, moderately twisted; margin coarsely but sometimes finely waved; surface slightly rugose, slightly bullate, semi-glossy, dark green; serrations medium in size and depth, slightly double, crenate.

25. **Grand Duke.** Habit upright-spreading, rather tall, medium stout; internodes medium. One-year bark purplish to brown; young shoots green to purplish tinged; pubescence none; lenticels medium in number, small, flush, russet; growing tips reddish tinged to reddish; young leaves medium green. Petiole wide-angled, moderately long, moderately thick, green to reddish tinged; glands 2, close to or on the blade, small, green. Leaf blade rather large, roundish-oval, flat to moderately saucer-folded; tip broad acute, slightly twisted; margin finely waved; surface smooth to slightly rugose and slightly bullate, semi-glossy, rather dark green; serrations moderately coarse, medium in depth, double, moderately serrate.

26. **Green Gage.** Habit upright-spreading, short, medium stout; internodes short. Two-year bark medium to dark brown; one-year bark purple to brown; young shoots green to purplish, glaucous; pubescence rather light, very short: lenticels medium in number, small, flush, russet; growing tips sometimes reddish tinged but often reddish or bronzed; young leaves medium green. Petiole rather wide-angled, short, medium thick, green to reddish tinged; glands 1-2, close to the blade, small, yellowish green, with depressed centers. Leaf blade rather small, oval, medium U-folded; tip short acute, sharp; margin medium-waved; surface smooth to slightly rugose and slightly bullate, semi-glossy to dull, rather dark green; serrations fine, rather shallow, double, dull serrate to crenate, regular.

27. **Gueii.** Habit upright-spreading, medium in height, rather stout; internodes short. Two-year bark medium brown; one-year bark light purplish to light brown; young shoots green to pink tinged; pubescence rather heavy; lenticels few, very small, flush, russet; growing tips reddish tinged to light reddish; young leaves moderately light green. Petiole wide-angled, rather short, moderately thick, reddish; glands 1-2, close to or on the blade, small, yellowish. Leaf blade moderately large, thick, roundish-oval, flat to broad U-folded; tip short, broad acute; margin slightly coarsely waved; surface moderately rugose, slightly bullate, somewhat semi-glossy to dull, medium green; serrations medium in size, rather shallow, double, crenate, rather regular.

28. **Hall.** Habit upright-spreading, medium in height, medium stout; internodes moderately short. Two-year bark dark brown, scarfskin on old bark; one-year bark greenish purple to dark brown. Young shoots green to purple; pubescence none to trace; lenticels rather numerous, small, flush, russet; growing tips reddish; young leaves medium green, slightly yellowish. Petiole wide-angled, medium in length, rather thick, green; glands 1-2, close to or on the blade, medium in size, slightly stalked, greenish, with depressed centers. Leaf blade medium in size, oval, flat to slightly broad U-folded, drooping; tip broad acute, twisted, slightly reflexed; margin somewhat finely waved to medium-waved; surface moderately rugose, slightly bullate, mostly dull, very slightly pubescent, medium green; serrations medium in size, medium in depth, double, dull serrate, rather irregular.

29. **Imperial Epineuse.** Habit spreading, moderately short, moderately slender; internodes rather short, zigzag. Two-year bark medium to moderately dark brown, smooth and rather shiny; one-year bark purple to brown; young shoots pink to purplish, glaucous; pubescence none to a trace; lenticels rather few, small, flush, russet; growing tips reddish tinged; young leaves light to medium green. Petiole wide-angled, short, slender, reddish to red; glands 2, rather close to the blade, rather small, often stalked, yellow, with depressed centers. Leaf blade moderately small, oval to obovate, medium to narrow U-folded; tip acute; margin moderately finely waved; surface smooth to bullate, somewhat semi-glossy to dull, rather light yellowish green; serrations rather fine, rather deep, double, dull serrate to crenate.

30. **Imperial Gage.** Habit upright-spreading, medium in height, medium stout; internodes short. Two-year bark greenish brown; one-year bark green to purplish to brown; young shoots green to slightly purplish, glaucous; pubescence light or occasionally medium; lenticels numerous, small, flush, russet; growing tips green to slightly reddish tinged; young leaves medium green, slightly yellowish. Petiole medium-angled, short, moderately thick, reddish tinged; glands 2, on the petiole, medium in size, greenish, round with depressed centers. Leaf blade medium in size, round-oval, broad U-folded, rather rigid; tip acute, slightly twisted; margin medium-waved; surface bullate, mostly dull, very slightly pubescent, medium grayish green; serrations rather fine, rather shallow, double, crenate.

31. **Italian Prune** (**Fellenburg**). Habit spreading, rather tall, slender to medium stout; internodes medium. Two-year bark dark grayish brown, much scarfskin; one-year bark purplish to brown; young shoots reddish tinged to purplish; pubescence none; lenticels few, small, flush, russet; growing tips reddish to red; young leaves medium green, often bronzed. Petiole wide-angled, moderately long, moderately thick, reddish tinged; lgands 2, usually close to but occasionally on the blade, medium in size, often stalked, greenish, slightly reniform, with depressed centers. Leaf blade rather large, long oval to obovate, saucer-folded to reverse keel-folded, drooping; tip acute, sometimes reflexed; margin moderately finely waved; surface slightly rugose, semi-glossy, very slightly pubescent, rather dark yellowish green; serrations medium in size, rather deep, double to triple, usually dull serrate to crenate, irregular.

32. **Lombard.** Habit upright-spreading, rather tall, moderately stout; internodes rather short. Two-year bark light to medium brown; one-year bark purple to brown; young shoots reddish tinged to dull purplish; pubescence none; lenticels moderately numerous, small, flush, russet, moderately conspicuous even up towards the shoot tips; growing tips green to slightly reddish tinged; young leaves medium green. Petiole wide-angled, rather short, medium thick, slightly reddish tinged; glands 1-2, close to or on the blade, moderately small, greenish. Leaf blade medium in size, oval, flat to broad U-folded, drooping; tip acute, twisted, reflexed; margin rather finely waved; surface bullate, semi-glossy, dark green; serrations medium in size, rather deep, double, dull serrate to crenate.

33. **Methley.** Habit upright-spreading, medium in height, rather slender; internodes rather short. Two-year bark medium brown; one-year bark purplish to red to brown, medium to fine scarfskin; young shoots reddish; pubescence none; lenticels medium in number, rather small, flush, russet; growing tips greenish to strongly reddish tinged; young leaves medium yellowish green. Petiole wide-angled, medium in length, moderately slender, dull reddish; glands 2-4, on the petiole, small, sometimes slightly stalked, yellowish. Leaf blade moderately small, oval, flat to broad V-folded; tip acute to slightly acuminate, slightly reflexed; margin even to slightly coarsely waved; surface moderately rugose, somewhat semi-glossy to dull, medium green; serrations fine, rather shallow, double, dull serrate, regular.

34. **Monarch.** Habit upright-spreading, medium in height, rather stout; internodes short. Two-year bark medium brown, much fine scarfskin; one-year bark green to slight purplish and light brown; young shoots green to pinkish tinged; pubescence heavy; lenticels very few, small, flush; growing tips reddish to red; young leaves medium green. Petiole moderately wide-angled, very short, rather thick, green to slightly reddish tinged; glands 1-2, close to the blade, small, greenish, round, with depressed centers. Leaf blade moderately small, roundish, broad U-folded, "cupped up" near growing tips, erect; tip mucronate, twisted; margin slightly coarsely waved; surface fine, moderately rugose to slightly bullate, semi-glossy, slightly pubescent, medium green; serrations fine, rather shallow, double, dull serrate to serrate, regular.

35. **Monitor.** Habit upright-spreading, rather tall, rather slender; internodes moderately long. Two-year bark dark greenish brown; one-year bark purplish to greenish brown, fine scarfskin; young shoots greenish to dull purplish tinged; pubescence none; lenticels rather numerous, medium in size, distinctly raised, russet, conspicuous; growing tips dull reddish; young leaves medium green. Petiole medium-angled, rather long, moderately thick, dull red; glands 2, close

to the blade, moderately large, reniform, greenish, with tendency to slough off early. Leaf blade rather large, oval, flat to reverse saucer-folded; tip acuminate; margin even; surface mostly smooth with principal veins depressed, rather glossy, medium green; serrations rather fine, rather shallow, double, crenate, regular.

36. **Pacific.** Habit upright-spreading, moderately tall, medium stout; internodes short. Two-year bark medium brown, much fine scarfskin; one-year bark slight purplish to brown; young shoots green to slightly reddish tinged; pubescence none; lenticels moderately few, small, flush, russet, fairly conspicuous; growing tips reddish tinged; young leaves moderately light yellowish green. Petiole wide angled, short, rather thick, reddish tinged; glands 2, usually well down on the petiole, medium in size, yellowish, with depressed centers. Leaf blade medium to moderately large in size, oval, flat or broad U-folded to slightly saucer-folded, often reflexed, moderately drooping; tip acute, often twisted; margin slightly medium-waved; surface smooth to slightly rugose, mostly dull, very slightly pubescent, medium yellowish green; serrations medium in size, rather shallow, double, dull serrate to crenate, regular.

37. **Pearl.** Habit upright, moderately short, medium stout; internodes rather short. Two-year bark medium to moderately dark brown, light to medium scarfskin; one-year bark purple to brown; young shoots slightly green to purplish; pubescence light, very short; lenticels rather numerous, medium in size, flush, russet; growing tips very red; young leaves medium green, often reddish. Petiole moderately wide-angled, moderately short, rather thick, reddish tinged to reddish; glands 2, on the petiole, moderately small, greenish to reddish, sometimes reniform, sometimes leafy-stalked, with slightly depressed centers. Leaf blade medium in size, roundish-oval, flat to slightly saucer-folded, sometimes slightly reverse saucer-folded, considerably drooping; tip acute, slightly twisted, reflexed; margin medium-waved; surface very bullate, slightly rugose, semi-glossy to glossy, slightly pubescent, rather dark yellowish green; serrations medium in size, moderately deep, double, crenate, rather regular.

38. **Pipestone.** Habit upright-spreading, tall, moderately stout; internodes rather long. One-year bark mostly green to slightly brown; young shoots dull green; pubescence none; lenticels numerous, rather large, slightly raised, russet; growing tips reddish tinged to reddish; young leaves medium bronzy green. Petiole medium-angled, moderately long, medium thick, reddish; glands usually 4 with 2 well down on the petiole, rather large, brownish green. Leaf blade rather large, oval to broad elliptic, flat to reverse saucer folded; tip long acute, slightly reflexed; margin even to slightly coarsely waved; surface moderately rugose, mostly dull, lightly pubescent, bristly, rough, medium yellowish green; serrations very fine, shallow, double to triple, crenate.

39. **Pond.** Habit upright-spreading, moderately tall, moderately slender; internodes moderately short. Two-year bark brown; one-year bark greenish to light brown; young shoots green to dull reddish or purplish tinged; pubescence none; lenticels numerous, small, flush, russet; growing tips light green to very slightly reddish tinged; young leaves medium green. Petiole wide-angled, short, medium thick, green; glands 2, usually very close to the blade, occasionally fairly well down on the petiole, medium in size, slightly stalked, yellowish green. Leaf blade rather small, round-oval, flat to slightly saucer-folded; tip blunt acute, twisted, reflexed; margin considerably waved, mostly finely, but sometimes coarsely; surface bullate to rugose, somewhat semi-glossy to dull, lightly pubescent, medium green; serrations coarse, rather shallow, slightly double, crenate, irregular.

40. **President.** Habit upright-spreading, rather tall, medium stout; internodes medium. Two-year bark rather dark brown, medium scarfskin, conspicuous lenticels; one-year bark purplish green to brown; young shoots green to purplish, glaucous; pubescence none; lenticels few, small, flush, russet; growing tips reddish tinged; young leaves moderately light yellowish green. Petiole very wide-angled, rather short, moderately thick, reddish tinged to moderately reddish; glands 0-2, very small, on the blade, yellowish green. Leaf blade moderately large, oval, flat to broad U-folded or saucer-folded, slight tendency to reverse keel-folded, moderately drooping; tip short acute, slightly twisted; margin coarsely waved; surface smooth to slightly rugose, very glossy, medium green; serrations very fine, shallow, serrate, regular.

41. **Red Coat.** Habit spreading, short, medium stout; internodes short. One-year bark reddish to brown; young shoots reddish tinged; pubescence none; lenticels numerous, small, slightly raised, russet; growing tips reddish; young leaves medium green. Petiole moderately wide-angled, medium in length, medium thick, reddish tinged; glands 2, fairly well down on the petiole, rather large, dull greenish. Leaf blade medium in size, oval to broad elliptic, flat to slightly broad U-folded, sometimes slightly reverse saucer-folded; tip rather long acute, slightly twisted, slightly reflexed; margin slightly coarsely waved; surface rugose, mostly dull, finely pubescent (moderately bristly), moderately light yellowish green, often mottled; serrations rather fine, rather shallow, double, dull serrate, regular.

42. **Red June.** Habit rather upright, medium in height, moderately slender; internodes moderately short. Two-year bark dark greenish brown; one-year bark greenish red to dark brown, coarse broken scarfskin; young shoots mostly reddish; pubescence none; lenticels numerous, moderately small, raised, russet, conspicuous; growing tips reddish tinged; young leaves rather light yellowish green. Petiole medium-angled, short, rather slender, reddish; glands 2-4, close to the blade, moderately large, yellowish, globose or reniform. Leaf blade moderately small, elliptic, medium to broad U-folded; tip acuminate, twisted; margin coarsely waved; surface slightly to moderately rugose, semi-glossy, moderately dark yellowish green; serrations rather fine, rather shallow, double, dull serrate, rather irregular.

43. **Sannois.** Habit upright, slightly spreading, rather short; internodes short. Two-year bark dark greenish brown; one-year bark purplish to brown; young shoots green to pinkish tinged; pubescence none to a trace; lenticels very numerous, small, flush, russet; growing tips reddish tinged; young leaves medium to dark yellowish green. Petiole wide-angled, short, thick, green; glands 1-2, close to or on the blade, small, green. Leaf blade moderately small, oval to slightly elliptic, medium U-folded, thick textured, reflexed; tip short acute, reflexed; margin medium-waved; surface moderately rugose or bullate, semi-glossy, rather dark green; serrations medium in size, rather deep, double, dull serrate.

44. **Santa Rosa.** Habit upright, medium in height, moderately slender; internodes medium. Two-year bark light brown, many lenticels; one-year bark green to brownish, fine scarfskin; young shoots green to dull reddish tinged; pubescence none; lenticels very numerous, moderately small, raised, russet; growing tips light green; young leaves light yellowish green. Petiole medium-angled, short, rather slender, green to reddish tinged; glands 2, close to or on the blade, small, yellowish green, reniform. Leaf blade small to medium, oval to elliptic to slightly obovate, rather broad U-folded, erect; tip moderately acuminate, slightly twisted; margin slightly coarsely waved; surface smooth to slightly rugose, fine, mostly dull, moderately light green; prominent light greenish veins; serrations rather fine, medium in depth, double, crenate, regular.

45. **Shipper's Pride.** Habit upright-spreading, medium in height, moderately stout; internodes short. One-year bark purplish to brown; young shoots green to reddish tinged; pubescence very heavy; lenticels few, moderately small, flush, russet; growing tips reddish tinged to reddish; young leaves medium bronzy green. Petiole wide-angled, extremely short, thick, green; glands 1-2, on the blade, small, yellowish. Leaf blade medium in size, round-oval, broad U-folded to saucer-folded; tip very short to obtuse; margin coarsely waved; surface slightly rugose, moderately dull, lightly pubescent, medium green with occasional mottling especially near the margins; serrations medium in size, shallow, crenate.

46. **Shiro.** Habit upright-spreading, rather tall, medium stout; internodes rather short. Two-year bark light brown; one-year bark greenish to reddish purple to brown; young shoots green to dull purplish; pubescence none; lenticels rather few, small, flush, russet; growing tips reddish tinged to reddish; young leaves rather light greenish. Petiole wide-angled, rather short, moderately slender, reddish, somewhat upcurved; glands 2-5, close to the blade to scattered, very small, leafy stalked, yellowish green. Leaf blade moderately small, elliptic to obovate, broad V-folded; tip fairly long acute, slightly reflexed; margin usually even; surface moderately rugose, semi-glossy to dull, medium green; serrations rather fine, shallow, double, crenate, only moderately regular.

47. **Shropshire.** Habit upright-spreading, branchy, medium in height, slender; internodes short. Two-year bark medium brown; one-year bark light purplish to brown, much grayish scarfskin; young shoots green to purplish; pubescence medium; lenticels few, small, flush, russet; growing tips reddish tinged; young leaves moderately light green. Petiole rather wide-angled, short, medium thick, reddish tinged; glands 1-2, close to or on the blade, small, slightly stalked, greenish. Leaf blade usually small, oval to long-oval, flat to broad V-folded; tip acute, slightly twisted, point of tip sharp; margin slightly coarsely waved; surface slightly rugose, dull, rather light green; serrations fine, medium in depth, double, moderately dull serrate, regular.

48. **Shropshire (English).** Habit moderately upright, rather short, rather slender; internodes short. Two-year bark rather dark brown; one-year bark greenish to light purplish to brown; young shoots green to slightly purplish; pubescence light to medium; lenticels few, small, flush, russet; growing tips reddish tinged; young leaves moderately light to medium green. Petiole wide-angled, short, rather slender, green; glands 1-2, close to the blade, small, often leafy-stalked, greenish. Leaf blade small, oval to elliptic, flat to rather broad V-folded; tip acute, twisted, reflexed, point of tip rounded; margin medium- to coarsely waved; surface rugose, slightly bullate, mostly dull, medium green; serrations moderately fine, medium in depth, double, dull serrate to crenate, rather irregular.

49. **Stanley.** Habit upright-spreading, tall, rather slender; internodes medium. Two-year bark light to medium brown, conspicuous lenticels; one-year bark purple; young shoots reddish tinged to purplish; pubescence none to a trace; lenticels rather numerous, small, flush, russet; growing tips reddish tinged to reddish; young leaves medium green. Petiole wide-angled, rather short, moderately slender, reddish; glands 2, on the petiole, medium in size, roundish, yellowish, with depressed centers. Leaf blade small to medium in size, oval to obovate, mostly rather narrow U-folded; tip acute, slightly twisted; margin medium-waved; surface slightly bullate, moderately rugose along midrib, somewhat semi-glossy to dull, medium yellowish green; serrations coarse, rather deep, double, dull serrate, irregular.

50. **Superior.** Habit spreading, rather tall, rather slender; internodes medium. Two-year bark brown; one-year bark green to brown, considerable fine broken scarfskin; young shoots green; pubescence none; lenticels few, small, slightly raised, russet; growing tips usually reddish tinged; young leaves medium green. Petiole moderately narrow-angled, medium in length, medium thick, green; glands 2-3, close to the blade or scattered, medium in size, yellowish, globose to slightly reniform. Leaf blade medium in size, elliptic, flat to broad V-folded; tip moderately acuminate; margin even; surface smooth to slightly rugose, dull, medium green; serrations fine, shallow, double, dull serrate, regular.

51. **Underwood.** Habit upright-spreading, tall, moderately slender; internodes medium. Two-year bark brown; one-year bark green to brown with rather fine scarfskin; young shoots dull reddish tinged to reddish; pubescence none; lenticels medium in number, very small, slightly raised, russet; growing tips reddish to red; young leaves rather light yellowish green, often tinged. Petiole wide-angled, medium in length, medium thick, red; glands 2-4, scattered, small, yellow, globose. Leaf blade rather large, oval, flat to saucer-folded, drooping; tip acute, twisted; margin even; surface smooth to slightly rugose, fine, dull, medium green; serrations medium in size, shallow, double, crenate, rather irregular.

52. **Washington.** Habit upright-spreading, rather tall, medium stout; internodes medium. Two-year bark medium olive brown, some scarfskin on older bark; one-year bark green to purplish to brown, brown extending rather far up; young shoots green to pink; pubescence light to medium, very short; lenticels few, small, flush, russet; growing tips reddish tinged; young leaves rather light yellowish green. Petiole rather wide-angled, short, very thick, slightly reddish tinged; glands 0-2, on the blade, very small, yellowish. , Leaf blade large, round-oval, flat to slightly saucer-folded, drooping; tip very short, twisted; margin slightly medium to coarsely waved; surface smooth to slightly rugose, semi-glossy, lightly pubescent, moderately light yellow green; serrations medium in size, medium in depth, double, crenate, moderately regular.

53. **Wickson.** Habit upright, medium in height, rather slender; internodes rather short. Two-year bark dull green to greenish brown, considerable scarfskin; one-year bark greenish, with fine netted scarfskin; young shoots green; pubescence none; lenticels moderately few, rather small, flush, russet; growing tips green to very slightly reddish tinged; young leaves light yellowish green. Petiole wide-angled, upcurving, short, medium thick, slightly reddish tinged; glands 2-4, usually close to the blade, medium to moderately small, yellowish, often reniform. Leaf blade rather small, narrow elliptic, medium U-folded, reflexed midrib; tip acuminate, slightly twisted, often moderately reflexed; margin coarsely waved; surface smooth, semi-glossy to dull, medium green; serrations fine, shallow, double, dull serrate, regular.

54. **Wright's Early.** Habit upright-spreading, rather tall, moderately stout; internodes rather short. Two-year bark medium to reddish brown; one-year bark medium brown with medium- to coarse-broken scarfskin extending the full length of the shoots; young shoots dull yellowish green; pubescence none; lenticels moderately numerous, medium in size, mostly flush, russet; growing tips green; young leaves moderately light yellowish green. Petiole wide-angled, short, thick, green to reddish tinged; glands 2-4, close to the blade or scattered, small to medium in size, yellowish, reniform and globose. Leaf blade medium in size, obovate, flat to reverse saucer-folded, drooping; tip small, long acute, reflexed; margin even; surface rugose, dull, medium yellowish green; serrations fine, very shallow, double, dull serrate to crenate, regular ,moderately distinct.

55. **Yakima.** Habit upright, rather tall, moderately stout; internodes moderately short. Two-year bark medium to rather dark brown, some scarfskin on older bark; one-year bark purple to slightly brownish; young shoots green to reddish tinged to purplish; pubescence none; lenticels medium in number, rather small, flush, russet; growing tips green to reddish tinged to moderately reddish; young leaves medium green. Petiole wide-angled, moderately short, thick, green to reddish tinged; glands 2-3, very close to the blade, large, moderately stalked, green, irregular reniform. Leaf blade medium in size, roundish-oval, flat (occasionally slightly saucer-folded to

slightly reverse keel-folded);tip acute, twisted, often slightly upcurved; margin coarsely to medium-waved; surface moderately rugose, slightly bullate, dull, lightly pubescent, medium gray green; serrations rather coarse, shallow, sometimes double, dull serrate to crenate.

56. **Yellow Egg.** Habit upright-spreading, tall, medium stout; internodes moderately long. Two-year bark rather light brown, some scarfskin on older bark; one-year bark pinkish to light brown; young shoots pink, slightly glaucous; pubescence trace to very light; lenticels medium in number, small, flush, russet; growing tips light green to reddish tinged; young leaves light to medium yellowish green. Petiole wide-angled, medium in length, moderately thick, reddish tinged; glands 1-2, very close to or on the blade, small, greenish. Leaf blade rather large, roundish-oval, flat to saucer-folded, slightly twisted midrib, drooping; tip acute, slightly twisted; margin typically medium-waved; surface rugose, slightly bullate, semi-glossy to dull, lightly pubescent, rather light yellowish green; serrations medium in size, medium in depth, double, dull serrate to crenate, irregular.

57. **Yellow Gage.** Habit upright-spreading, medium in height, medium stout; internodes rather short. Two-year bark light to medium brown, considerable scarfskin; one-year bark purplish to brown; young shoots green to purplish; pubescence a trace; lenticels medium in number, small, flush, russet; growing tips reddish; young leaves moderately light to medium green. Petiole wide-angled, medium in length and thickness, reddish tinged; glands 1-2, close to or on the blade, moderately small, orften slightly stalked, yellowish, with depressed centers. Leaf blade medium in size, roundish-oval, flat or broad U-folded to slightly saucer-folded, somewhat drooping; tip acute; margin medium-waved; surface smooth to slightly rugose and bullate, semi-glossy to glossy, very slightly pubescent, medium green; serrations rather fine, rather shallow, double, dull serrate, regular.

Literature Cited

1. Alderman, W. H., and J. S. Shoemaker. Use of leaf characters in identification of plum varieties. Amer. Soc. Hort. Sci. Proc. 22:264-269. 1925.

2. French, A. P. Plant characters of cherry varieties. Mass. Agr. Expt. Sta. Bul. 401. 1943.

3. Hedrick, U. P. The plums of New York. 1911. Albany.

4. Shaw, J. K. Leaf characters of apple varieties. Mass. Agr. Expt. Sta. Bul. 208. 1922.

5. Shaw, J. K., and A. P. French. The identification of apple varieties from non-bearing trees. Mass. Agr. Expt. Sta. Bul. 274. 1931.

6. Shaw, J. K. Descriptions of apple varieties. Mass. Agr. Expt. Sta. Bul. 403. 1943.

7. Shoemaker, J. S. Eliminating variety mixtures in nursery trees. Ohio State Hort. Soc. Proc. 60:42-51. 1927.

8. Upshall,W. H. Nursery stock identification (plums, pears, peaches, cherries). Ontario Hort. Expt. Sta. Bul. 319. 1926.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 414 June 1944

Bacteria and Rural Water Supplies

By James E. Fuller

This is an attempt to give intelligent direction to what constitutes sanitation in rural water supplies.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

AUG 30 1944

BACTERIA AND RURAL WATER SUPPLIES

By James E. Fuller, Research Professor of Bacteriology

THE BACTERIOLOGICAL TESTING OF WATER

For some years the Department of Bacteriology at the Massachusetts State College and Experiment Station has maintained a service for the bacteriological examination of privately owned rural water supplies. This service is intended primarily to serve farms and rural homes. No samples are accepted from supplies that serve the public as such, except the Amherst town supply, which is tested as a service to the community in which the college and station are located.

The methods used in the bacteriological testing of water are those formulated by the American Public Health Association, in cooperation with the American Water Works Association, and published under the title, "Standard Methods of Water Analysis." These methods are generally accepted as standard by state, municipal, and private laboratories throughout the United States.

Experience in this laboratory, in the testing of farm and other rural water supplies raises questions as to how strictly the results of the "Standard Methods" examinations of such supplies should be interpreted. It happens not infrequently that a well or spring would be condemned if the laboratory results were interpreted as strictly as these methods direct, even though an inspection of the premises may fail to disclose any source of dangerous pollution. Often water from a well or spring will continue to give unsatisfactory laboratory tests when reexamined, even though every effort has been made to eliminate all possible sources of pollution.

If a farm or rural water supply is condemned because laboratory tests continue to indicate pollution, and efforts to remedy the situation fail, the logical solution of the problem is to locate a new supply. Often this is not practicable, and it may even be impossible. A small farm may not offer a site any better than the one condemned; and even if a new site can be located, the farmer may not be able to easily afford the expense of developing a new source of supply and of properly equipping and protecting it.

Several years ago the author and his associates became interested in the problems of sanitation of farm water supplies, and began to conduct experiments to determine to what extent positive laboratory tests actually mean dangerous pollution and how rigidly the "Standard Methods" procedure and interpretation should be adhered to in evaluating the sanitary quality of water from farms and other rural supplies.

The Development of Standard Methods

The practical application of bacteriology had its beginning about the time of our Civil War, when the French scientist, Louis Pasteur, proved that "microbes" in wine were the cause rather than the result of a fermentation that was spoiling the wine. During the next forty years the bacteria that cause many important infectious diseases were discovered. Once these discoveries were made, it became possible to determine the sources of the diseases, and it was found that the bacteria causing some of them could be traced to water, milk, and foods; for instance, that tubercle bacilli could be carried by milk, and that both milk and water could spread the bacilli of typhoid fever, dysentery, and enteritis.

The next logical step for scientists was to try to develop methods for detecting the presence of dangerous bacteria in water, milk, and foods. Results were not encouraging so far as methods for routine use were concerned, so investigators turned next to the development of methods which would indicate the existence of conditions capable of spreading infections. What we now know as the various "Standard Methods" are the outgrowth of these activities.

The first step towards standardizing the bacteriological testing of water was taken by the American Public Health Association in 1894, and as a result a convention of American bacteriologists, in 1895, appointed a committee "to draw up procedures for the study of bacteria (in water) in a uniform manner." This committee's report was published in 1898 and served as a guide for the testing of water supplies until the publication, in 1904, of the first edition of the "Standard Methods of Water Analysis," compiled by a committee of the American Public Health Association collaborating with other bacteriologists. The first edition of the "Standard Methods of Milk Analysis" was published in 1910. Both publications included chemical as well as bacteriological tests. Since then, "Standard Methods" have been developed for the examination of shellfish and various other kinds of foods, for detection of food poisoning, for evaluation of methods of cleaning eating and drinking utensils, and for a number of other purposes.

In the development of standard methods, it is necessary that they be sponsored by some organization large enough, and well enough established and regarded, to give authority to their recommendations. The American Public Health Association is such an organization in America. In some instances other organizations in a particular field collaborate with the Association. The "Standard Methods of Water Analysis" is prepared and published jointly by the American Public Health Association and the American Water Works Association. It is fortunate that these organizations are not political and have no authority to require the adoption and use of their methods. Health authorities in general recognize the desirability of employing uniform laboratory procedures so that results in different places can be compared and standards of quality to be met by supplies of milk, water, and other substances can be made uniform. Consequently, the "Standard Methods," particularly those for the testing of milk and water, have been generally adopted over the country by municipal and state legislation.

Standard methods for any purpose are necessarily arbitrary. There is usually more than one way to do anything, and there are likely to be differences of opinion as to which of several procedures is better or best. In establishing a standard method, efforts are made to simplify something which usually is quite complex. No simple method devised for bacteriological purposes can tell more than a part of the story. No single medium can detect all of the types of bacteria present in water or milk, for instance; the employment of one temperature for incubation of cultures will fail to produce growth of bacterial species that prefer another temperature; the acidity or alkalinity of a medium will stimulate growth of some types of bacteria at the expense of others; if materials such as dyes are added to a medium to select certain species of bacteria, it naturally follows that growth of others is prevented.

Standard methods, to be most effective, should be employed and their results interpreted by technicians who are well educated in science and know the values and limitations of the methods. Unfortunately, that too often is not the case. Many technicians in small municipal laboratories, and sometimes in industrial laboratories, have been trained to make tests without knowing what they mean. Such technicians work by a rule-of-thumb method and have no alternative but to interpret results as directed in the pages of a book.

It is also unfortunate that records of tests, particularly of water and milk supplies, are frequently made available to the public. Few lay people have had the requisite training to enable them to interpret results of tests, and they do not know the background of the materials being tested. In the case of milk tests, one should never judge a supply on the basis of one or two tests. Too many things can happen to a sample of milk after it leaves the dairy to make the result of a few tests conclusive. A supply should be considered unsatisfactory only after check tests have been done, and after inspections have been made all the way from the cow to the laboratory to determine the source of trouble. A water test can be evaluated properly only if one has information regarding the source of the water, and this is best obtained by a sanitary survey of the source.

In the discussion of the experiments presented here, the author has no intent or desire to find fault with any "Standard Method." No trained scientist, and this includes those responsible for setting up the methods, would claim infallibility for any test proposed. Tests must be kept simple and easily made if they are to be useful in testing samples frequently and in large numbers. The intent is that tests should be only general indicators of the quality of the materials tested. Results should be interpreted with judgment and discretion. It has been said that in medical diagnosis a laboratory test should be considered as equivalent to one symptom only. A similar value should be placed on bacteriological tests included in the various "Standard Methods." All of the "Standard Methods" procedures are being scrutinized constantly by their sponsors to keep them up to date. Promising new methods are investigated and some of them are included in each new edition.

Although it is not specifically stated in the publication, the "Standard Methods of Water Analysis" have been developed particularly for the testing of public water supplies. The main reason for this is that professional people in the fields of public health and water works engineering are the ones primarily concerned in promoting the development of analytical and testing methods for water, and public water supplies are naturally their main interest.

Public water supplies are usually chlorinated at least, and in many instances chlorination is preceded by sedimentation and filtration. Logically, such water is expected to be free from all types of bacteria that would give positive laboratory tests, even though some of these types might have little immediate sanitary significance. The standard of interpretation is desirably severe. It often happens, however, that raw water from wells and springs may give positive tests of doubtful sanitary significance, and a sensible interpretation of results becomes a difficult problem.

In the eighth edition of the "Standard Methods of Water Analysis," this statement appears: "At the same time, it is recognized that any one book cannot possibly meet all of the needs of those engaged in laboratory work in this field and that special methods must be developed to meet local conditions. . . . It is realized that this edition must represent only another milestone in progress . . ." In the spirit of that statement, it was the purpose of the experiments reported in this bulletin to attempt to find a basis for the interpretation of the "Standard Methods" when employed for the testing of raw waters from farms and rural homes, and to carry out certain studies that would permit a better understanding of the bacteria responsible for positive tests of uncertain significance.

Dangers From Polluted Water

The reason for making bacteriological examinations of water supplies needs little explanation, because almost everyone knows that the purpose is to prevent the spread by water of bacteria that cause infectious diseases. The public, however, is not so well informed as to the diseases one may contract by drinking polluted water, so it may be well to digress for a brief statement on that point.

It is not uncommon for persons bringing water samples to our laboratory to ask for bacteriological examinations because they fear that such diseases as tuberculosis, scarlet fever, or infantile paralysis may be spread by water. The answer to such inquiries is that dangerous bacterial pollution of water comes from the human sewage which is from human intestines, and consequently the diseases one risks when he drinks polluted water are intestinal diseases. In the United States, and particularly in the North Atlantic seaboard states, typhoid fever and dysentery are the only bacterial diseases one need be much concerned about from contaminated water supplies. Some health authorities believe that virus from cases of infantile paralysis may be found in sewage when there are cases about, and that there is some danger of water supplies being contaminated with the virus. Present evidence, however, does not indicate that one need greatly fear getting this disease from water.

One usually thinks of typhoid-fever germs as coming only from persons ill with the disease; but another source of danger is the typhoid carrier, a person who has recovered from his illness but who may continue to excrete typhoid bacilli in his stools for months or even years. In fact, carriers may be people who have had cases of typhoid fever so mild that they were never recognized as such. One of the most widely publicized typhoid carriers was "Typhoid Mary" Mallon, who was reliably said to have been responsible for more than 50 cases of typhoid fever in homes where she worked as a cook, and who was strongly suspected of having been responsible for a water-borne epidemic of more than 1,300 cases of the disease. Many other instances of typhoid carriers have been proved and the carrier condition is well understood.

The possibility that dysentery may be spread by carriers is not so well known, but reference to standard books on bacteriology and public health indicates that such carriers undoubtedly exist.

What is a Bacteriological Examination of Water?

Bacteriology is a highly specialized science, and unless one has studied the subject he is not expected to know much about bacteria except that they are "germs" that cause diseases. Consequently, it is natural for the layman to assume that the bacteriologist examines water directly for the presence of typhoid or dysentery bacteria. That procedure is not practicable for several reasons. These bacteria are not constantly present in a water supply, even though it may be considered dangerous, and it is easily possible to miss them in a laboratory examination of a water that may contain enough of them to start an epidemic. Another important factor is that in polluted water other bacteria are usually present in such numbers that their growth in culture media prevents or masks the growth of the relatively few typhoid or dysentery bacteria that may be present.

Since direct examination of water for typhoid and dysentery bacteria is not practicable, the logical procedure is to look for evidences of sewage pollution which is the most likely source of these bacteria. Consequently, the bacteriological examination of water supplies is designed to detect the presence of bacteria of the colon bacillus (*Escherichia coli*) group, which has been accepted for many years as an indicator of sewage pollution. The colon bacillus is normally present in large numbers in the large intestines (colons) of human beings and warm-blooded animals, and derives its name from that fact. The bacillus is passed in fecal evacuations and so finds its way into sewage. The colon bacillus itself is not considered harmful when taken internally. It is just an indicator of possible harm from other sources.

Even if a laboratory examination reveals the presence of colon bacilli, it does not necessarily follow that the water is dangerous to health. There have been few cases of typhoid fever or bacillary dysentery reported in New England in recent years, and germs of these diseases get into water only from infected people. It is wise, however, to err on the side of safety; so a water that yields an unsatisfactory bacteriological test should be regarded as possibly dangerous. Even though water polluted by sewage may not necessarily be dangerous, it should be considered dirty water. No one would want to eat food or drink milk that had been polluted by sewage, and one should be equally particular about the water he drinks. Water may be so clear as to be sparkling, and have no taste or odor, but it still may be polluted sufficiently to be unclean or even dangerous.

Method of Examination

The bacteriological examination of water depends upon the fact that the colon-bacillus group of bacteria, known to bacteriologists as the coliform group, will ferment lactose (milk sugar) and produce gas. A fluid culture medium is made up of water, beef extract, peptone (a product from digested protein), and a small amount of lactose. This medium is put into test tubes, which are filled about one-quarter full, and smaller test tubes or vials are inverted in the larger ones. The large tubes are plugged with cotton and the medium is sterilized under steam pressure in an autoclave, which is essentially an elaborated pressure cooker. When the medium has been sterilized and then cooled, it is ready for use.

Water samples should be collected in sterilized bottles. In the laboratory, bottles are sterilized with steam under pressure. If samples are brought into the laboratory in containers prepared in the home, such containers should be held in actively boiling water for at least ten minutes before being used, and should then be carefully stoppered with stoppers or covers that have also been boiled. When samples are taken, care should be used to avoid touching either the mouth of the bottle or the stopper with the fingers or any other object that might cause contamination. Water standing in pipes or pumps should be drained off so that samples taken are representative of the source of supply.

When the samples reach the laboratory, portions of the water are transferred to the test tubes of culture media by means of sterile glass pipettes. The tubes are incubated at 37°C. (body temperature) and examined at the end of 24 hours to see if the bacteria present have produced gas. If gas has formed, it will be trapped in the small inverted vials and will displace the fluid in them. If no gas is observed at the first examination, the tubes are incubated another 24 hours. If no gas appears in any of the tubes by this time, the water is considered satisfactory and is so reported. If, however, gas appears in any of the inverted tubes, contamination is indicated.

Some estimate of the degree of contamination can be made by considering the percentage of the inoculated tubes that show gas and the quantities of water that have been put into them. For instance, the usual procedure in testing a water sample is to inoculate a series of tubes with one milliliter of water each and another series with ten milliliters each (1,000 milliliters = about one quart). Gas formation from the one-milliliter inoculations is considered an indication of a more serious degree of pollution than that in tubes receiving ten milliliters each. If a water is suspected of being very badly polluted, a series of tubes may be inoculated with one-tenth of a milliliter each.

The appearance of gas in the fermentation tubes is termed a "presumptive test," and in itself is not sufficient evidence that the water contains bacteria of the coliform group. There are some other species of bacteria, not indicative of sewage pollution, that may form gas from lactose; and it sometimes happens that two species of bacteria acting together (symbiosis) may produce gas from lactose where neither alone could do it. If gas is produced under either of these conditions, the result is termed a false presumptive test. Consequently, a positive gas test must be confirmed.

The next step is to remove, with a sterilized wire loop, some of the fluid from fermentation tubes showing gas and streak it on a differential solid culture medium on which coliform bacteria will give characteristic growth. The two media most used for that purpose in this country are Endo's agar and Eosin-methylene blue agar. The agar in these media gives them a solid base, and both contain proper food materials to support the growth of bacteria. These media also contain dyes that prevent the growth of unimportant bacteria and cause the growth of coliform bacteria to assume a characteristic appearance. One or the other of these media is used, not both at the same time.

If no growth occurs on the differential solid medium, it can be assumed that gas in the lactose-broth tube was not caused by coliform bacteria and no pollution is indicated. If, however, there is growth on the solid medium, the test must be further confirmed. A sterilized wire loop is employed again, and some of the bacterial growth is taken from the differential medium and put into fermentation tubes identical with those used for the preliminary test. It sometimes happens that the solid medium will produce growth that appears to be coliform bacteria, and yet no gas will be produced when it is put again into lactose broth. Usually, however, it is the non-characteristic growth that will fail to produce gas in the refermentation tests. On the other hand, non-characteristic growth not infrequently is confirmed as coliform bacteria.

In the examination of municipal water supplies, the "Standard Methods" procedure does not require confirmation if gas appears within the first 24 hours of incubation. However, experience in our laboratory in testing water from privately owned rural supplies has indicated the desirability of confirming all positive presumptive tests from such waters.

Differentiation of Coliform Bacteria

The coliform group of bacteria is made up of a number of similar and closely related species. We may think of them, perhaps, as being arranged in a line. At one end of the line is the colon bacillus (*Escherichia coli*) and at the other end is the aerogenes bacillus (*Aerobacter aerogenes*). In between is a miscellaneous lot of species known as intermediates of the group. Some of these will closely resemble *Escherichia coli*, some the *Aerobacter aerogenes*, and some will seem to be somewhere between these two. All of these species behave alike with bacteriological stains, and they are indistinguishable from one another when viewed under the microscope.

If all of these species had the same sanitary significance, it would be unnecessary to go further than to identify them as coliform bacteria. It is the opinion of many who have worked with these bacteria that the *Escherichia coli* is the primary indicator of sewage contamination of water, and that *Aerobacter aerogenes* usually comes from soil and indicates pollution of water from the ground's surface. The meaning of the intermediates is not clear and is the subject of much controversy and discussion. It is natural, however, to suppose that the sanitary significance of these intermediates depends upon the closeness of their relationship to either *Escherichia coli* or *Aerobacter aerogenes.*

To begin with, all of the coliform bacteria ferment lactose and produce gas. Then, they all look alike when viewed through a microscope. When cultures of these bacteria are made with media containing dyes (Endo's or eosin–methylene blue agar), it is possible to make some differentiation of them. From that point on, it is necessary to inoculate the cultures into media designed for the purpose of making possible the separation of the species. A number of tests have been devised and employed for the purpose, and four of them are now in common use.

These four tests employed for differentiation of the group are designated by the collective term of IMViC test. Each of the four capital letters indicates a test and the small "i" is put in to supply a necessary vowel for the second syllable. The word is generally written "Imvic." The tests are as follows:

I, indole test. This depends on the fact that certain of the coliform bacteria will produce a chemical substance, indol, from an amino acid, tryptophane, incorporated in a fluid medium. Indol can be detected by a specific color reaction when the proper reagents are employed.

M, methyl-red test. When certain species of bacteria are grown in a broth containing dextrose (glucose), they will produce acid which is detected by adding an indicator, methyl red, to the broth after incubation is completed. The indicator range of the methyl red is such that a positive test indicates rather strong acid production. This is commonly designated as the M. R. test.

V, Voges-Proskauer test. This test depends on the ability of certain bacterial species, growing in dextrose broth, to produce a chemical compound known as acetyl-methyl-carbinol. This can be detected by a color reaction when the proper reagents are employed. This test is termed the V. P. test.

C, sodium citrate test. In this test a fluid medium is prepared in which sodium citrate is the sole source of carbon. If bacteria inoculated into the medium can utilize the carbon, growth is evident and the test is termed positive.

The reactions of *Escherichia coli* and *Aerobacter aerogenes* to these tests are shown in the following table:

	Indole	M.R.	V.P.	Sodium citrate
Escherichia coli	+	+	−	−
Aerobacter aerogenes	−	−	+	+

All possible combinations of these reactions may be encountered among the intermediates of the coliform group of bacteria. All may be positive; all may be negative; or any combination of positives and negatives may occur. One group, other than *E. coli* and *A. aerogenes*, recognized by some investigators, gives a negative V. P. test and is positive for the other three tests. The name *Citrobacter* has been proposed for this group, and a close relationship is thought to exist between this group and *E. coli*. It appears to be a species of *E. coli* that can utilize sodium citrate.

The section of this bulletin that follows immediately is a general summary of some of the experimental work that was done in the effort to arrive at a better understanding of the relationship of coliform bacteria to rural water supplies in order that more intelligent interpretations of results might be made. At the end are placed comprehensive abstracts of the several studies, to supply essential technical data for those who want them. These abstracts are arranged on the basis of logical relationship and sequence, and are designated by capital letters. These designations are referred to in the general summary to relate it to the abstracts.

SUMMARY OF EXPERIMENTAL STUDIES

The experimental studies reported in this bulletin developed logically, step by step, as is indicated by the order of discussion of the subjects in this summary, and of the arrangement of the abstracts.

The first study (A) was concerned with results of tests of rural water supplies. For some years numbers of water samples from farms and rural homes have been brought into this laboratory to be tested bacteriologically. The "Standard Methods" procedure has been employed. Gradually, as the results of tests accumulated, it began to appear that a disproportionately large number of water-supply sources were being condemned on the basis of the laboratory tests as being unfit for household use.

This department has no extension service, but it was possible sometimes to make inspections of the locations, and it often happened that inspection failed to reveal any cause for the water being unsafe for use in the home. Considering all of the evidence, it seemed that the Standard-Methods test was too exacting for privately owned rural water supplies. That was the inspiration for the studies that followed.

The laboratory study was begun with a collection of 223 cultures of coliform bacteria from 172 water samples brought in for routine testing. The "Imvic" tests were applied to these cultures with the result that only 60.5 percent of them were classified as colon bacilli and the balance were aerogenes bacilli or intermediates of the coliform group. Considering that the colon bacillus indicates pollution from sewage, and that the aerogenes bacillus and intermediates usually are from the soil, nearly 40 percent of the cultures must have come from surface wash. If they indicated sewage pollution at all, it was likely that it had been remote both as to time and location. On the basis of this survey, it seemed that rural raw-water supplies should not be condemned without a sanitary survey of the premises unless the colon bacillus itself is found in the water samples examined.

A supplementary study was made (B) of some abandoned wells located in the hilly country east and northeast of Amherst. This region once was settled and farmed, but the land is poor and for years it has been largely abandoned as farming land. Most of it has been used for timber land, and occasionally for hay fields. Most of the homes have been removed, or have fallen down, and it has been many years since any one has lived at the sites employed for the study.

Seven wells were selected. All were located in open hay fields, and were so situated that little surface water would flow into them. The fields were not fenced and consequently no domestic animals were pastured in them. Hence, there was little chance for dangerous pollution to get into the water. The wells, being old, were curbed with loosely laid field stones and were covered with flat stones, both of which would unavoidably admit some surface water.

On the basis of sanitary surveys, these wells would have been approved as sanitary, yet bacteriological tests strictly interpreted would have condemned the water of all of them as unfit for household use. A majority of positive cultures from these wells were aerogenes bacilli or coliform intermediates. Thus, the study of the wells confirmed the information obtained from the study of water samples sent in to the laboratory to be tested.

The results from the water samples and from abandoned wells indicated the need for a simplification of the procedure for detecting sewage contamination in water. It would be desirable if one medium could be found to take the place of the several required by the "Standard Methods." Two new media favorably reported by investigators were tried (C). They are designated in the abstracts as B. G. B. and B. C. P. broths. The first medium contains bile and a dye intended to promote the growth of sewage types of coliform bacteria and suppress non-sewage bacteria; the second contains dyes for the same purpose and an indicator for the detection of acid which coliform bacteria produce in media containing sugars.

These media were inoculated with water from 76 routine samples, and the standard lactose broth was inoculated for comparison. The results did not encourage the substitution of either of the media for the "Standard Methods" procedure, even though the latter requires two media and several days to get results.

In the next study (D) several media were investigated to determine their ability to detect false presumptive tests which have already been explained. Several combinations of species capable of symbiotically producing gas from lactose have been described, and the abstract of this study lists some of these. It is quite common for at least one member of a symbiotic association of bacteria to so resemble the coliform bacteria as to make its detection difficult. A number of media commonly employed in water analyses were tried with several symbiotic combinations of bacteria to see if one or more media could be found that would fail to support growth of the symbiotic bacteria. Included were the "Standard Methods" media, the B. G. B. and B. C. P. broths employed in the previous study, and a special agar medium (Noble's) for which much was claimed, at the time, as a differential medium. B. G. B. gave better results that did lactose broth or B. C. P., but it has been claimed that the B. G. B. medium will prevent growth of gas production by some colon bacilli (*E. coli*). Noble's agar medium gave results that were encouraging, but it has disadvantages that make its use impracticable for most technicians; so again the experiments failed to find any short cut to dependable results.

The colon bacillus produces acid very actively when cultivated in broth media containing simple sugars, particularly if the sugar happens to be dextrose (glucose) or lactose. The aerogenes bacillus and many of the intermediates produce acid weakly or not at all. These facts are the basis for the methyl-red test widely used to differentiate the colon bacillus from other members of the group. The next studies (E, F) were based on observations previously made that when metallic iron or erythrosin (a dye) were incorporated in a broth containing dextrose and a buffer to partially counteract the acid, and the mixture was inoculated with the colon bacillus, the iron was dissolved or the erythrosin was precipitated.

In this study, cultures of colon and aerogenes bacilli were inoculated separately into both iron–dextrose broth (E) and erythrosin–dextrose broth (F). The results of the experiments indicated that these methods, if properly developed, might be used to advantage in detecting the degree of acid production by coliform bacteria, thus making it possible to grade organisms on the basis of acid production. While neither of these methods appeared to be desirable for routine testing of water, they probably could be developed for differential study of coliform and other bacteria.

At this point it seemed logical to spend some time studying the effects of environment on the bacteria themselves. The first of the environmental factors studied was indol. The source of indol has already been explained, and so far these studies had been concerned with indol production only as a means of identifying cultures. This study was concerned with the possible effect of indol on the growth of coliform bacteria.

As the colon bacillus multiplies in the human colon it is constantly in the presence of substantial concentrations of indol which it and other intestinal bacteria produce from waste residues of digested food. Consequently the colon bacillus must be able to tolerate indol, which is known to retard or prevent growth of some other species of bacteria. Since the aerogenes bacillus and many of the coliform intermediates develop in soil and decaying plant residues on the ground, they would not be in contact with much indol, if any, and conceivably might be less able than the colon bacillus to tolerate the compound. This was the argument on which the study was based.

Different concentrations of indol (G) were added to a fluid culture medium and tubes of the medium were inoculated with a number of cultures each of the colon bacillus, the aerogenes bacillus, and intermediates. After a suitable incubation period the amount of growth in the tubes was determined. It was observed that the colon bacillus was somewhat more resistant to the indol than were other coliform bacteria. The differences were not great enough, however, to make possible the distinction between fecal and non-fecal coliform bacteria.

Bile is another intestinal factor that might be expected to have some influence on the growth and characteristics of intestinal bacteria as compared with non-intestinal forms. Bile has been employed effectively in the isolation of typhoid-fever bacteria from stools and blood of typhoid fever patients. Bile is also a constituent of the B. G. B. medium employed in a study already described (C). At least one investigator (see abstract H) has reported that in the small intestines of humans he found aerogenes bacilli and in the colons of the same individuals he found only colon bacilli. He offered the opinion that the aerogenes bacilli had been changed into colon bacilli by the intestinal environment.

In the study here reported (H) a number of cultures of aerogenes bacilli were cultivated for a number of months in media containing bile and bile salts. The cultures were examined by the Imvic tests before the experiment was begun and from time to time as the experiment progressed. There was no change at any time in the Imvic reactions of the cultures, which indicated that if the aerogenes were changed to coli in the intestine, the change probably would not be due to bile or bile salts alone.

In the last study (J) of the series the effect of bacteriophage on colon and aerogenes bacilli was investigated. From its derivation, the word "bacteriophage" means something that will eat bacteria, and that is the definition of the agent. It is not known just what a bacteriophage is. Some authorities claim that it is just a chemical digesting agent, probably an enzyme. Others insist that it is a living thing that digests bacteria just as bacteria digest various food substances that they live on. If the bacteriophage is a living thing, it is so small that it cannot be seen through powerful laboratory microscopes, and it can pass through fine filters that will not permit bacteria to pass through them.

Bacteriophages have specific relationships, and a bacteriophage that will digest one species of bacteria will not harm another. No bacteriophages have been found for many species of bacteria, but they have been demonstrated for those common in the intestinal tract. Bacteriophages can be isolated from substances, water and sewage especially, that are heavily seeded with bacteria. The kind of bacteriophage one can isolate depends upon the material and the bacteria growing in it. Efforts have been made to purify water supplies by inoculating them with a suitable bacteriophage. It has been demonstrated that the agent can alter the characteristics of bacteria that are able to resist its digesting action.

In the study here reported (J) a coli bacteriophage was isolated from raw sewage, and a culture of the colon bacillus was isolated from the same sewage. Experiments proved that the bacteriophage would digest its related coli culture isolated from the same sewage. Then other cultures of both colon and aerogenes bacilli were placed, separately, in bottles of water (two liters each) and the bacteriophage was added. The cultures were exposed thus to the action of the bacteriophage for five months.

Before the experiment was started, and from time to time for its duration, the several types of bacteria were reisolated from the bottles of water and examined by the several differential tests already described. No changes were noted in either the appearance or the cultural characteristics of the bacteria employed, except a slight change in their serological reactions which are too complicated to explain here. One cannot conclude too much from experience with only one bacteriophage, but the experiment indicated that if bacteriophage were present in standing water, like that of the abandoned wells mentioned earlier (B), it might destroy its related bacteria but it would not alter them into other forms.

Concluding Comment

To the reader it may seem that the experiments did not yield anything very definite, and in some respects that is true if each study is considered by itself. However, the total result of the experience served to crystallize some ideas that have been of substantial help in evaluating the methods employed and the results obtained in testing raw water supplies from farms and other rural homes.

The first two studies emphasized the importance of using care in interpreting results of tests. The "Standard Methods" provide the only generally accepted bacteriological procedure for the testing of water, and are designed primarily for use with public water supplies which usually are chlorinated at least, and which often are sedimented and filtered. On the basis of experience and the experiments reported, the conclusion was arrived at that the results of tests of untreated private supplies must be interpreted liberally and emphasis must be placed on the presence of the colon bacillus rather than on the aerogenes bacillus or intermediates of the coliform group. It is desirable, where possible, to have a sanitary survey of the source of water tested.

The studies of the several media for the presumptive and confirmation tests failed to find any substitutes for the media specified by "Standard Methods" for these purposes. The studies with dissolved iron and precipitated erythrosin indicated that the two procedures might be developed for certain differential examinations of bacterial cultures, but there seemed to be no justification for attempting to develop them into testing methods. Studies on the effect of bile,

bile salts, and bacteriophage furnished evidence that cultures of both the colon and aerogenes bacilli are stable, and that environment will not change their characteristics easily if at all. Therefore, each would have its meaning in evaluating the sanitary quality of a raw water supply.

Finally, intangible values were derived from the studies that may not easily be set down on paper. After doing practical work and experimenting in any field, one acquires experience and a capacity for judgment that cannot be specifically explained, but that are of substantial value in the doing of his work.

ABSTRACTS

In the abstracts which follow, the numbers in parentheses refer to articles in the literature reference list which terminates this bulletin. Some of these references are to work done in this laboratory and others are to sources of methods and other data published elsewhere.

A. Studies of Rural Water Supplies

The first study (1) was concerned with 172 water samples examined bacteriologically in the laboratory and condemned as unfit for drinking purposes. Each sample represented an individual source of supply. From these samples 223 cultures of coliform bacteria were isolated and studied. For comparison, 178 cultures of coliform bacteria were isolated from human feces and studied in the same way. For the most part, the cultures from human sources represented different individuals.

All of the cultures were studied for their "Imvic" reactions, and the uric acid test was added because of the interest that attached to it at that time (1933). Media were prepared and used as directed in the "Standard Methods" (2). The only deviation from these procedures was the use of Werkman's method (3) for the Voges-Proskauer test. The indol test was not included in the edition of "Standard Methods" then in use. The medium and procedure employed were the same as those incorporated in a later edition of "Standard Methods" (21). Goré's plug test (4) was employed for the detection of indol.

A summary of the differentiation of the cultures on the basis of their Imvic reactions is shown in table 1. In this table the organisms are separated into ten groups on the basis of their reactions.

Table 1.—Coliform Cultures Isolated From Raw water Samples and From Feces Grouped on Percentage Basis According to Differential Tests.

Test	Groups									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Indol	+	+	−	−	−	−	−	+	+	−
Methyl-red	+	+	+	−	−	−	+	−	−	+
Voges-Proskauer	−	−	−	+	+	+	−	+	+	−
Sodium citrate	−	+	+	+	+	−	−	−	+	−
Uric acid	−	+	+	+	−	+	+	+	−	−
Cultures from water, percent	60.5	20.1	8.5	3.6	3.1	1.8	0.9	0.4	0.4	0.4
Cultures from feces, percent	93.2	1.7	1.1	2.2	0.5	0	0	0	0	1.1

Of the fecal bacteria, 93.2 percent were in the first group (*Escherichia coli*), 2.2 percent were in the fourth group (*Aerobacter aerogenes*), and 4.6 percent in the other ten groups (coliform intermediates). Of the cultures from water, 60.5 percent were in the first group, 3.6 percent in the fourth group, and 35.9 percent in the other ten groups. If the uric-acid test is ignored and the organisms are grouped on the basis of their Imvic reactions, the result will be to combine group IV with group V, and group VII with group X. On this basis, the percentages of cultures in the *E. coli* group are unchanged. Among the fecal strains the percentage of *A. aerogenes* is slightly increased to 2.7 percent and that of intermediates is reduced slightly to 4.1 percent. The percentage of *A. aerogenes* among the cultures from water is increased from 3.6 to 6.7 percent and that of the intermediates is correspondingly reduced to 32.8 percent. Most of the intermediates among this lot of cultures are in the second group, for which the name "Citrobacter" has been proposed. The sanitary significance of this group and of the other intermediates is a much debated subject, but they are not generally considered to be indicative of immediate fecal pollution.

B. Water from Abandoned Wells

A second study (5) was made to confirm the results from water testing. Seven wells on farms long abandoned were selected for study as described earlier in this bulletin. All were removed from any immediate possibility of sewage pollution, and all were so situated that a minimum of surface water could get into them.

Results of the bacteriological examination of water from these wells emphasized the results reported above. All of the wells would have been condemned by the "Standard Methods" as unsatisfactory for drinking purposes; yet sanitary inspections failed to disclose any source of dangerous pollution. Over 50 percent of the cultures isolated proved to be coliform intermediates. A strict interpretation of the results according to the "Standard Methods" appeared to be unsatisfactory, and yet there was no other accepted basis that could be used.

C. Comparative Study of Presumptive Media

The next logical step appeared to be a study of media that had been proposed for use in the bacteriological testing of water. The purpose was to find a medium or method that would indicate accurately and directly the sanitary significance of the bacteria present in raw waters. In this study (6) the media employed were brilliant green bile broth (7) and methylene blue erythrosine brom cresol purple broth (8). The first will be designated as B. G. B. and the second as B. C. P. "Standard Methods" lactose broth, designated as S. M., was employed for comparison. All media were made and used as directed in "Standard Methods" (9). These three media were employed in parallel in testing 76 samples of raw water.

The quantities of each water sample inoculated into each medium were 10, 1, 0.1, 0.01, and 0.001 ml. Five tubes of each quantity were inoculated, making 1,900 tubes of each medium for the 76 water samples. All tubes were examined for gas production after 24 hours' incubation, and all negative tubes were incubated an additional 24 hours and examined again. All positive gas tubes were confirmed on Endo's medium with refermentation tests in S. M. lactose broth.

A summary of the results is found in table 2. B. G. B. gave about the same number of positive presumptive tests and a higher percentage of confirmations than were obtained with S. M. lactose broth, and both of these media gave much better results than did B. C. P. "Standard Methods" (9) includes B. G. B. as a tentative method, and it has been proposed as a confirmatory medium in the place of Endo's or eosin methylene blue agars. In this study, however, no particular advantage in the use of B. G. B. was discovered that would give it preference over S. M. lactose broth for presumptive tests. Use was made also of B. G. B. as a confirmatory medium. The reader is referred to the published article (6) for details.

TABLE 2.—COMPARISON OF S. M. LACTOSE BROTH, B. G. B. BROTH, AND B. C. P. BROTH AS PRESUMPTIVE MEDIA.

	Lactose broth	B. G. B. broth	B. C. P. broth
Number of tubes inoculated	1,900	1,900	1,900
Percent positive, 24 hours	46	47	23
Percent confirmed, 24 hours	39	43	21
Percent positive, 48 hours*	57	55	43
Percent confirmed, 48 hours*	44	49	35

*The 48-hour figures are totals for the whole period and include the 24-hour figures.

D. False Presumptive Tests

This study (10) was made to test the value of several media in detecting or eliminating false presumptive reactions. Three fluid media and four solid media were employed. The fluid media were Standard Methods lactose broth, brilliant green bile (B. G. B.), and brom cresol purple (B. C. P.), all of which had been employed in the preceding study. The solid media were Endo's agar, eosin methylene blue agar (E. M. B.), MacConkey's agar, and the special agar of Tonney and Noble (11). The latter medium was obtained in dehydrated form (Difco) and the others were prepared according to directions in the Standard Methods of Water Analysis (9).

Several combinations of bacterial species previously reported to cause false presumptive gas production in lactose broth were investigated. Pure laboratory stock cultures were employed for making the combinations, which were as follows:

A. *Staphylococcus* and *Pseudomonas aeruginosa.*
B. *Staphylococcus* and *Proteus vulgaris.*
C. *Staphylococcus* and *Salmonella schottmuelleri.*
D. *Streptococcus faecalis* and *Proteus vulgaris.*
E. *Streptococcus faecalis* and *Salmonella schottmuelleri.*

Three staphylococcus strains, *S. aureus*, *S. citreus*, and *S. albus*, were employed separately in the combinations.

The media were inoculated with these combinations of organisms and examined after 24 hours' incubation. All negative results were incubated an additional 24 hours and examined again. Results are shown in table 3.

Lactose broth failed to give a false presumptive with combination A, even though such a combination has been reported to form gas from lactose. B. C. P. gave false presumptive tests with all of the combinations, although fermentation was slow. B. G. B. gave the best results of the fluid media and should be the best of the three for eliminating false presumptives. It has been claimed that

B. G. B. is so selective in its action that it prevents growth, or gas formation at least, by some strains of coliform bacteria.

Of the solid media employed for confirmation, both Endo's agar and E. M. B. agar gave false confirmations with the same combinations of bacteria: A, C, and D. MacConkey's agar gave false confirmations with combinations A and D. The Tonney and Noble medium did not give reactions with any of the combinations that could have been confused with coliform reactions, and thus it would seem to be an ideal medium for use in water analysis. The medium, however, has limitations, not the least of which is the difficulty of preparing and using it.

TABLE 3.—COMBINATIONS OF NON-COLIFORM BACTERIA GIVING POSITIVE TESTS.

Presumptive tests

Combination	Lactose broth		B. G. B. broth		B. C. P. broth	
	24 hr.	48 hr.	24 hr.	48 hr.	24 hr.	48 hr.
A	–	–	–	–	–	+
B	+	++	–	–	–	+
C	+	++	–	–	–	+
D	–	+	+	+	–	+
E	–	+	–	–	–	+

Confirmation tests

Combination	Endo's agar		E. M. B. agar		MacConkey's agar		Tonney and Noble agar	
	24 hr.	48 hr.	24 hr.	48 hr.	24 hr.	48 hr.	24 hr.	48 hr.
A	+	+	+	+	+	+	–	–
B	–	–	–	–	–	–	–	–
C	+	+	+	+	–	–	–	–
D	+	+	+	+	+	+	–	–
E	–	–	–	–	–	–	–	–

Note: + on confirmatory media means that readings could be interpreted as coliform reactions.

E. Dissolved Metallic Iron

For many years bacteriologists have observed that the colon bacillus produces a greater degree of acid from carbohydrates than the aerogenes bacillus or many of the intermediates. This fact is the basis of the methyl-red test designed by Clark and Lubs (12). In the course of certain experiments in this laboratory to determine the possible influence of metals on bacterial growth, it was observed that when certain members of the coliform group were cultivated in unbuffered dextrose broth containing metallic iron, sufficient acid was produced to dissolve the iron. Application of the potassium ferrocyanide test detected the dissolved iron. Experiments were done (13) to investigate the correlation of dissolved iron with the methyl-red test.

In the first experiment a buffer (K_2HPO_4) was added to Clark and Lubs' glucose broth containing iron filings. The concentrations of buffer ranged from 0.2 to 0.5 percent, at intervals of 0.1 percent. Both *E. coli* and *A. aerogenes* cultures were inoculated separately into this medium. Tests for dissolved iron, made after suitable incubation periods, showed that 0.3 percent buffer in the medium gave the best differentiation between *E. coli* and *A. aerogenes*. Tubes inoculated with *E. coli* gave positive tests for dissolved iron and those inoculated with *A. aerogenes* gave negative tests. A few drops of a 2 percent solution of $K_3Fe(CN_6)$ added to a tube gave a blue color if iron had been dissolved. The color was deeper in cultures with a greater degree of acidity because more iron was dissolved.

To determine the pH value at which iron goes into solution, tubes of the sterile medium containing iron filings were prepared. Sterile acetic acid was added in quantities to give values ranging from pH 4.5 to pH 6. These tubes were uninoculated and were incubated for the same length of time as were the cultures. Above pH 5.14, no dissolved iron was detected; at pH 5.05, the results were plus-minus; and at pH 4.97 to 4.99, they were plus or double plus.

A series of 236 coliform cultures, including E. *coli*, *A. aerogenes*, and intermediates, was differentiated on the basis of the Voges-Proskauer, methyl-red, sodium citrate, and uric acid tests. Then these cultures were inoculated separately into buffered glucose broth containing iron filings. After 48 hours' incubation, tests for dissolved iron were made. Results may be seen in table 4.

TABLE 4.—COMPARISON OF METHYL-RED TEST WITH TESTS FOR DISSOLVED METALLIC IRON.

	Number of cultures	M. R.	Fe +	Fe +−	Fe− or ?
E. coli	36	+	34	1	1
	27	+−	6	3	18
Citrobacter	5	+	5	0	0
A. aerogenes	81	−	6	0	75
Intermediates	24	+	11	3	10
	41	+−	8	2	31
	9	?	0	0	9
	13	−	6	2	5
Summary:					
M. R. +	65		50	4	11
M. R. +−	68		14	5	49
M. R. − or ?	103		12	2	89

From the table it may be observed that all but 11 of the M. R. positive cultures gave plus or plus-minus reactions for dissolved iron. The failure of these eleven cultures and of most of the methyl-red plus-minus cultures to give positive tests may be explained possibly by the observed fact that the pH value did not go as low in cultures containing metallic iron as in those with the same buffer concentration but no iron.

F. Erythrosin Precipitation

A similar study was made (14) of the precipitation of erythrosin by acid-producing coliform bacteria as an indicator of the amount of acid produced. It had been observed, in some previous experimental work, that acid-forming bacteria precipitated the dye in a medium containing dextrose.

The medium employed was the same as that employed for the dissolved-iron study (Clark and Lubs' medium with 0.3 percent K_2HPO_4), except that 0.1 percent of erythrosin was used instead of metallic iron. The cultures, for the most part, were from the same stock cultures as those employed in the dissolved-iron study. Readings were made after 48 hours' incubation. Results are shown in table 5.

These results closely resembled those obtained with metallic iron. By separate experiment with acetic acid as the acidifying agent in the medium, it had been demonstrated that at 37° C. erythrosin began to be precipitated at pH 5.1 and that precipitation was practically complete at pH 4.9.

TABLE 5.—PRECIPITATION OF ERYTHROSIN.

Cultures	Positive	Negative
E. coli	102	1
Citrobacter	51	17
A. aerogenes	23	113
Intermediates	53	15

G. Indol Tolerance of Coliform Bacteria

This study (15) was based upon reports of other investigators that, although indol has been shown to inhibit bacterial growth, *E. coli* is quite resistant to its effects. It has even been suggested that indol production may be the mechanism by which *E. coli* retains its dominant position among intestinal flora (literature cited in published paper).

Tubes of Standard-Methods lactose broth were prepared and quantities of indol (solution in 70 percent alcohol) were added to give the concentrations shown in table 6. The bacterial cultures inoculated into the medium consisted of 173 strains of *E. coli*, 155 of *A. aerogenes*, and 83 of coliform intermediates. These cultures were classified by means of Voges-Proskauer, methyl-red, sodium citrate, and uric acid tests. The final results, after 48 hours' incubation, are shown in table 6.

TABLE 6.—INDOL TOLERANCE OF COLIFORM BACTERIA.

	Dilution of indol and number of strains inhibited						Total cultures tested
Organism	1:1500	1:1800	1:2000	1:2300	1:2500	1:3000	
E. coli	173	169	151	69	0	0	173
A. aerogenes	155	155	135	92	25	0	155
Intermediates	83	77	65	41	4	0	83

Results indicate that *E. coli* had the greatest resistance to indol, *A. aerogenes* the least, with the intermediates in between. The difference, however, was not great enough to have any apparent significance or use in indicating the fecal origin of *E. coli* or the non-fecal origin of coliform bacteria.

H. Bile Salts and *Aerobacter aerogenes*

Norwood and Webster (16) have suggested that in the human intestine *E. coli* of the colon may be a derivative of *A. aerogenes* existing in the small intestine, and their report suggested the next study (17).

If intestinal environment should be able to convert *A. aerogenes* into *E. coli* or intermediates, it seemed that bile or bile salts, because of their concentration in the intestine, could well be decisive factors in effecting such a conversion.

Thirty strains of *A. aerogenes* were selected for the study. They had been isolated from water and classified on the basis of the Imvic reactions and the uric acid test. The cultures had been carried on nutrient agar slants for three years, and had given constant differential reactions when retested periodically.

The medium was 1 percent lactose broth buffered with K_2HPO_4. Bacto oxgall, sodium glycocholate, and sodium taurocholate were added separately to portions of the medium. One series of 1 percent and another of 5 percent oxgall or bile salt were prepared. Cultures were inoculated into the media and incubated at 37°C. Once each week each culture was transferred to a fresh tube of the same medium.

At the end of five months of this treatment the cultures were tested for the differential reactions already mentioned, as well as with lactose broth and Endo's medium. Gram-stained smears were also examined. The cultures retained all of their original differential reactions, which indicated that bile or bile salts alone are not likely to convert *A. aerogenes* into other forms of coliform bacteria.

J. Bacteriophage

It is an accepted fact that bacteriophage is able to cause mutations among 'phage-susceptible bacteria. This is summarized by d'Herelle (18), who states that bacteria, exposed to the action of bacteriophage, undergo mutations that are frequently unstable but that may become fixed.

It was the purpose of the present study (19) to investigate the possibility that bacteriophage might so alter cultures of *E. coli* and *A. aerogenes* as to produce mutants that would give differential reactions of other coliform bacteria, and particularly of the intermediates.

A culture of *E. coli* was isolated from sewage, and a homologous bacteriophage was isolated from the same sewage. The technique of d'Herelle (18) was employed. The medium employed in isolating the bacteriophage was Rakieten's (20) Savita broth. Other media were made and used as directed in the Standard Methods of Water Analysis (9).

Two-liter quantities of sterile tap water were inoculated with the bacteriophage. Cultures of *E. coli* (including the homologous culture), and of *A. aerogenes* were inoculated into the bottles and kept at room temperature for five months. Control inoculations were made in water with no bacteriophage added. From time to time re-isolations were made from the bottles and tested, with results as follows:

The biochemical reactions of the several cultures of bacteria employed were studied. Tests were lactose broth fermentation, Endo plates, Imvic tests, and sodium malonate. Reactions were unaltered except that some cultures of the homologous *E. coli* produced atypical colonies on Endo's agar. These same re-isolated cultures displayed increased resistance to the bacteriophage.

The cultures, both homologous and non-homologous, that were subjected to the bacteriophage action were agglutinated by much higher dilutions of their specific sera than were the parent cultures.

No striking mutations were produced in the study.

References

1. France, R. L. Jour. Bact., 25: 623-625 (1933).
2. Standard Methods of Water Analysis, American Public Health Assoc., N. Y., 6th ed. (1925).
3. Werkman, C. H. Jour. Bact., 20: 121-125 (1930).
4. Goré, S. N. Ind. Jour. Med. Res., 8: 505-507 (1921).
5. Fuller, J. E. Unpublished data, Mass. Expt. Sta. (1933-4).
6. France, R. L. Jour. Amer. Water Works Assoc., 28: 785-793 (1936).
7. Jordan, H. E. Jour. Amer. Water Works Assoc., 24: 1027-1053 (1932).
8. Dominick, J. F., and Lauter, C. J. Jour. Amer. Water Works Assoc., 21: 1067-1076 (1929).
9. Standard Methods of Water Analysis, American Public Health Assoc., N. Y., 7th ed. (1933).
10. Fuller, J. E., and Kimball, E. D. Abstract., Mass Expt. Sta.. Bul., 327: 20 (1936).
11. Tonney, F. O., and Noble, R. E. Jour. Amer. Water Works Assoc., 23: 1202-1209 (1931).
12. Clark, W. M., and Lubs, W. A. Jour. Inf. Dis., 17: 160 (1915).
13. Syrocki, A. V., Fuller, J. E., and France, R. L. Jour. Bact., 33: 185-192(1937).
14. France, R. L., and Fuller, J. E. Zent. Bakt., II, 97: 312-314 (1937).
15. France, R. L. Jour. Bact., 32: 211-214 (1936).
16. Horwood, M. P., and Webster, R. A. Jour. Bact., 33: 21 (1937).
17. Fuller, J. E. Proc. Soc. Exptl. Biol. and Med., 38: 507-510 (1938).
18. d'Herelle, F. The Bacteriophage and its Behavior. (English trans., Smith). Williams and Wilkins, Baltimore (1926).
19. Fuller, J. E., and Bondi, A., Jr. Abstract, Mass. Expt. Sta. Bul. 347: 27 (1938).
20. Rakieten, M. Yale Jour. Biol. and Med., 4: 807-818 (1932).
21. Standard Methods of Water Analysis, American Public Health Assoc., N. Y., 8th ed. (1936).

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 415 June, 1944

Sunflowers as a Crop

By Karol J. Kucinski and Walter S. Eisenmenger

Sunflowers as a farm crop deserve consideration in Massachusetts because of their merits as a feed for poultry and other livestock in this area where adequate and satisfactory supplies of feed are of foremost concern.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

AUG 30 1944

SUNFLOWERS AS A CROP

By Karol J. Kucinski, Research Assistant, and Walter S. Eisenmenger, Research Professor, of Agronomy

General Considerations

Sunflowers have been grown to some extent in nearly all parts of this country, either for the seed or as an ensilage crop. Some varieties are grown as ornamental plants. In Missouri, California, and Illinois they are grown chiefly for the seed; while in the northern part of the United States, in Canada, and at high altitudes where the summers are short and the temperatures so low that corn does not do well, they are grown for forage.

Although interest in the sunflower has recently been increasing because of the many new uses being found for it, our forefathers years ago learned many of its values. They knew that the plant produces a good birdseed; that beekeepers consider it a source of fine honey and wax; that the seed is exceptionally rich in oil of high quality, suitable for human food as well as for making paints and fine soaps; that the oil cake is valuable for fattening cattle, pigs, sheep, pigeons, and rabbits; and that the sunflower stalk, if treated similarly to flax, yields fiber in large quantities.

Europeans, especially Russians, have long known the value of the sunflower, and the peasant population has always eaten the seed, it being not uncommon for youngsters to carry some in their pockets to crack and eat as our boys do peanuts. The oil found in sunflower seeds (about 20 to 32 percent) is considered a delicacy by the European cook.

In this country the sunflower seed is used primarily as an ingredient of scratch feeds for poultry, while the little oil that is extracted is used in making lard substitutes and in paints.

In the midst of an all-out war, with the accompanying shortages and high cost of feeds, there may be justification for growing crops which it might not be feasible or economical to grow under normal conditions. Poultrymen and individuals keeping hens for their own home use might well give earnest consideration to the growing of sunflowers, since the seed is an exceptionally good conditioner of poultry if used to supplement the regular feed.

For the past five or six years sunflowers have been grown at the Massachusetts Agricultural Experiment Station in the hope of finding out whether the crop is adapted to our soil and climatic conditions. Results of these tests are very encouraging, showing that the crop can be grown and will yield seed abundantly. However, to the best of our knowledge, no one in the State is now growing sunflowers in commercial lots, probably because of the lack of near-by mills for processing the oil and the prohibitive cost of transportation to mills in the Midwest.

It has been charged that the growing of sunflowers has an effect on the soil that may be detrimental to the succeeding crop. This may be true under semiarid conditions or in seasons of limited rainfall. However, this has not been borne out in experiments in the Connecticut Valley when tobacco was the succeeding crop, in spite of the fact that tobacco is very sensitive to effects of the preceding crop.

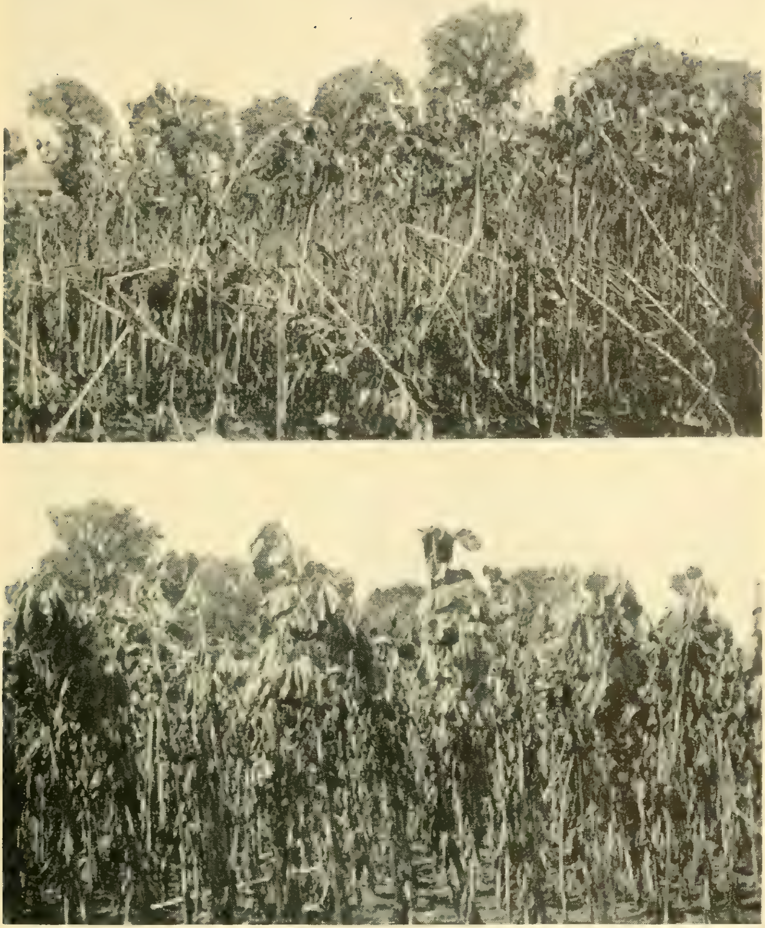


Figure 1

Upper: Two Sunflower Plants per Hill — Crop Almost a Complete Failure.
Lower: One Sunflower Plant per Hill — Strong Stalks with Large Seed Heads.

Growing the Crop

Sunflowers will grow successfully in Massachusetts on any land which will produce field corn. A light loam is preferable to a heavy wet soil. The field should be prepared by plowing, disking, and smooth harrowing, similar to the seed bed preparation made for corn planting. Sunflowers are hardy to light frost, and can be planted when it is safe to plant field corn. The plants are much more resistant to frost when they first come up than at the four or six leaf stage, but frosts late enough in the season to cause damage at these latter stages are rare. A growing period of 120 to 140 days, depending on the season, is sufficient for maturity of the seed in Massachusetts.

Sunflowers do well using corn fertilizer, which can be applied either in hills or broadcast. A 5-10-5, 5-8-7, or 3-12-6 grade of fertilizer, at the rate of 400-500 pounds per acre if applied in hills, and double that amount if broadcast, is sufficient for soils of average fertility. For a small area, the "Victory" grade of fertilizer, 5-10-5, may be used at the rate of about 15 pounds per thousand square feet in hills, or 30-35 pounds broadcast.

Field trials have shown that the best spacing is one seed every 18 inches in 36-inch rows. When the seeds are planted too close or too many in a hill, the plants will be small and thin and too weak to withstand any strong windstorm. The two pictures in Figure 1 show comparative results obtained with two ways of planting. In the West where large areas are planted, the crop is ordinarily seeded with a standard make corn planter with special plates made for the purpose; but it has been found satisfactory to plant small areas by hand. It takes about five to seven pounds of seed to plant an acre of sunflowers. The seed is usually planted not quite so deep as corn — only about one inch below the surface of the ground.

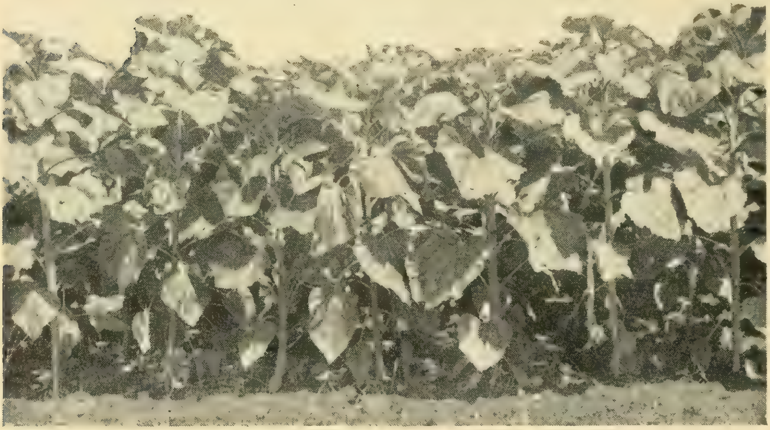


Figure 2. Young Sunflower Plants.
The Large Leaves Shade the Ground Preventing the Growth of Weeds.

The same implements can be used for cultivating sunflowers as for corn, and the methods are similar. The labor involved in taking care of sunflowers during the growing season is very little, since the plant starts to grow rapidly and soon shades the ground completely, killing any weeds that may survive the one or two early hoeings. Because of its thick vegetative cover (Figure 2), the sunflower plant serves admirably in ridding infested areas of obnoxious weeds.

The sunflower heads are usually harvested during the latter part of September. "Mammoth Russian" sunflower has an average height, just before harvesting, of about twelve feet, with seed heads which measure ten to twelve inches across. Figure 3 shows typical sunflower heads at the time of harvest. It has been found best to cut the sunflower heads off the stalks and place them singly on boards or dry ground to dry for about two weeks. This drying facilitates the removal of the seed from the head by striking the head against some object or rubbing the head on a very coarse wire screen. For home use as a poultry feed supplement, winnowing is not necessary. The seed should be stored in a dry place, safe from mice or birds. Some poultrymen have found it desirable to leave the seed attached to the head, feeding several heads daily to their chickens and letting them do the work of removing the seeds.

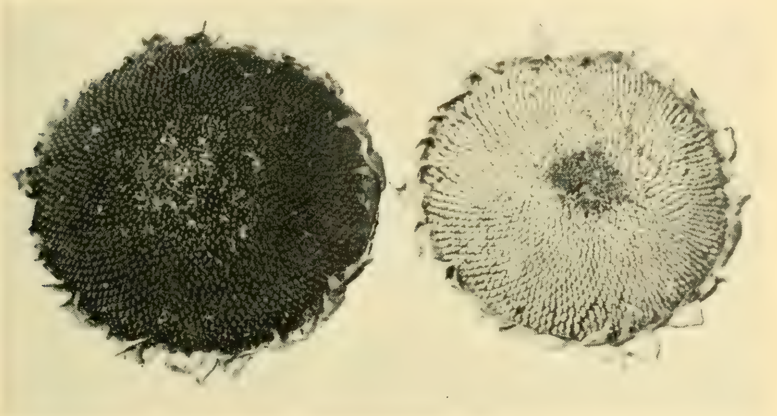


Figure 3. Typical Sunflower Seed Heads at Time of Harvest — Black African and Mammoth Russian Varieties.

The yield of seed varies greatly, and the average yield in the principal producing sections of this country is much less than was obtained at this station. In Massachusetts, depending on the fertility of the soil and the season, yields should average a ton of clean seed per acre. At the Experiment Station yields as high as two tons of seed per acre have been obtained. The wholesale price of sunflower seed as quoted on the west coast by the "Oil, Paint and Drug Reporter" ranges from 21½ to 24½ cents per pound (February 29, 1944). Even yields one-half that obtained at this station would be large enough to warrant consideration of this crop.

The varieties most commonly grown are Jumbo, Black African, Mammoth Russian, Manchurian type, and White Beauty. Figure 4 shows typical seeds of these varieties. The Mammoth Russian, a tall variety with striped seeds, is perhaps the most common and gives very good results. Sunflowers are very highly cross-pollinated and plots for seed must, therefore, be carefully isolated from other sunflowers. Constant selection of seed must be practiced if the strains are to be maintained; otherwise, sunflowers rapidly revert to the wild type. Seed should be obtained from a reliable seed concern. Ornamental varieties of sunflowers, of which there are many, are not of agricultural value since they produce very little seed.

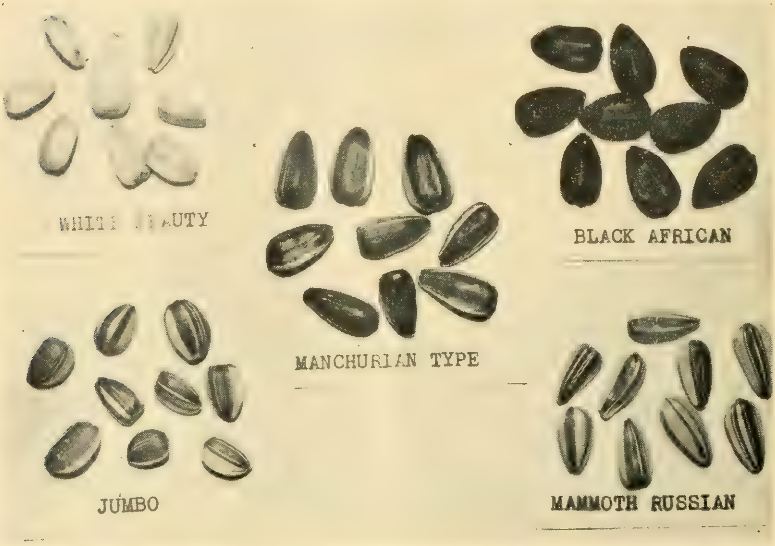


Figure 4. Typical Seed Varieties.

Diseases and Pests

A rusting of the lower leaves of the sunflower plants was the only ailment encountered in our trials. In severe cases the leaves turned brown completely and died. However, there was no evidence that the disease materially reduced the yield of the crop. Control measures consist of rotating the crop and plowing under the stalks.

Sunflower seeds are subject to infestation by the weevil. However, very little damage from this cause has been noticed in Massachusetts. This pest seems to develop in the head and inside the hull of the seeds before the seeds are fully mature. Seed which appears to be free from weevil when harvested may, after a month's storage, show weevil holes bored from within, which damage the grade of the crop. After the weevils leave the hull, they apparently never again bother the seed; hence it is possible to determine the weevil damage at this time, for it will not be any greater a year or so thereafter.

Some pest trouble has been observed in which slight damage has been caused by an insect boring into the heart of the plant stalk and eating out the pith; but this insect does not touch the seeded head.

Birds sometimes pick some of the seeds out of the sunflower heads where only a few plants are grown. The loss of seed due to birds is negligible, however, if the area of sunflowers is large and not surrounded by woods.

There is an element of risk involved in the growing of the crop which should not be entirely overlooked. Sunflowers are susceptible to damage from windstorms to the same degree as corn. Wind lodging can be prevented to some extent by so spacing the plants at the time of seeding that thick, strong stalks are produced.

Uses for the Sunflower Stalk

Poultrymen who grow sunflowers for feed may want to use the sunflower stalks and leaves for poultry house litter. With the cooperation of the Department of Poultry Husbandry at this station, trials have been made with chopped sunflower stalks as poultry litter. Results indicate that this material makes very good litter, having no objectionable features provided the stalks are chopped fine enough. The material used in these trials was chopped with an ensilage cutter. Figure 5 shows chopped sunflower stalks which were used as litter in the station trials.

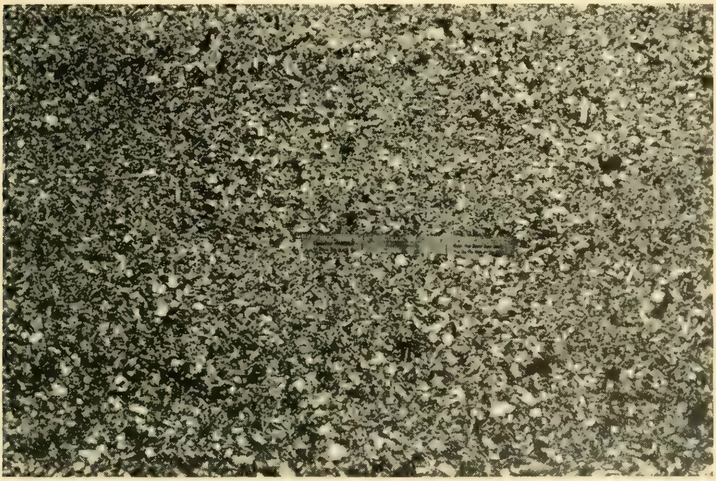


Figure 5. Chopped Sunflower Stalks Used as Litter in Hen House.

Although the ensiling of sunflowers may not be of particular interest to poultrymen, yields as high as nineteen tons per acre were obtained when the crop was used for this purpose, which compares favorably with the yield of corn. Feeding trials show that if the sunflower plant is ensiled while its leaves and stalks are still green, cattle seem to relish the silage and thrive on it. If the sunflowers are grown entirely for ensiling, they should be cut when the seed is in the dough stage. If the plant is cut too early, it will make a "sloppy" silage and if cut too late, it is apt to be dry and woody.

Sunflowers for Winter Bird Feeding

It is the practice of some bird lovers to put sunflower seeds out in bird feeding stations during the winter months. Sunflower seed is ideal for this purpose, but it has been very hard to purchase the seed locally for the supply is limited. Any birds fancier having land available can easily assure his winter bird friends their energy producing seed by growing a few heads of sunflowers in a corner of his garden or flower bed. Those growing sunflowers on a larger scale can often obtain premium prices from their local dealer who may be anxious to get seed for his winter bird feeding customers. Because of the restricted use of the seed, however, those desiring to engage in its production had best assure themselves of a market before undertaking the enterprise.

Publication of this Document Approved by Commission on Administration and Finance
5m (a) 7-44-14630

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 416 June, 1944

Relation of Intensity to Egg Weight and Egg Production

By F. A. Hays

Intensity is one of the most important inherited characters affecting egg production. This study brings out important relationships between intensity, egg weight, and egg production in an improved flock.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

AUG 30 1944

RELATION OF INTENSITY TO EGG WEIGHT AND EGG PRODUCTION

By F. A. Hays,
Research Professor of Poultry Husbandry

Introduction

Intensity or rate of laying is one of the most important inherited characters affecting egg production. Pearl (1912) developed a theory on the mode of inheritance of high egg production in which he emphasized the importance of winter production. Goodale (1918) was the first investigator to point out the importance of high intensity in breeding for egg production. Dryden (1921) emphasized the importance of intensity in relation to annual egg production. Hurst (1921) reported that high winter rate depended upon a single dominant gene. Hays (1924) pointed out that high winter rate depended upon two dominant complementary genes. Hays and Sanborn (1927a) stated that mean winter clutch size was a very satisfactory measure of intensity and showed that clutch size was governed in inheritance by two dominant genes. Knox, Jull and Quinn (1935) recommended gross winter rate as one of the most useful measures of intensity. Lerner and Taylor (1936) consider net winter rate obtained after deducting pauses of seven or more days as the best approximation of the winter rate of laying.

The relation of intensity to egg size has been studied. Atwood (1923) showed that there was a significant correlation ranging from −.13 to −.88 between mean monthly production and mean monthly egg weight. Hays (1930a) reported a correlation of −.3157 ± .0164 between mean clutch size to January 1 and mean egg weight for the same period. Hays (1934) found a correlation of .3001 ± .0314 between winter clutch size and time to standard egg weight in Rhode Island Red pullets.

The importance of high intensity in relation to egg production has been investigated by a number of workers. Hays and Sanborn (1927a, 1932) emphasized the importance of high intensity in breeding for high egg production. Hays and Sanborn (1927b) reported a partial correlation of .4944 ± .0101 between winter clutch size and annual egg production. Knox, Jull and Quinn (1935) found the correlation between rate of laying up to March 1 and annual production to be about .62 in White Leghorns and Rhode Island Reds. Taylor and Lerner (1935) consider the rate of laying to be one of the most important characters in breeding for egg production. Jull (1940) showed the association of high winter rate with annual egg production in a flock of 946 Rhode Island Reds. Tomhave (1941), by selection for high intensity, was able to show significant progress.

Data Available

The data included in this report are intended to furnish more complete information concerning the relation of intensity to egg weight and egg production in Rhode Island Reds bred for high fecundity. The birds used in the study include six generations hatched from 1937 to 1942. All records are based on the pullet year, beginning with the first pullet egg and terminating in 365 days.

Relation of Age at First Egg to Egg Weight and Intensity

1. *Age at First Egg and March Egg Weight*

For pullets hatched in March and April, egg weights taken during the month of March represent the maximum egg weight for the first laying year according to the observations of many investigators. In this study, mean egg weights for the month of March were recorded on 612 pullets representing six generations. These birds were divided into two groups with respect to age at first egg: 212 individuals with an age range at sexual maturity from 140 to 179 days; and 400 birds with an age range from 180 to 269 days. The birds in the first group should carry both genes E and E' for early sexual maturity according to Hays (1936). The latter group should carry either gene E or gene E' alone.

The *very early maturing group* gave the following constants:

Number of birds	212
Mean age at first egg—days	167.94
Age standard deviation	± 7.95
Mean March egg weight—grams	59.95
Egg weight standard deviation	± 4.19
Coefficient of correlation	+ .1402 ± .0454

The above data show that the variability was very low both in age at sexual maturity and in March egg weight. Regression of egg weight on age at sexual maturity was linear. The coefficient of correlation was positive but of such low magnitude as to give odds of but 19 to 1 of being significant. In view of this fact it is reasonable to assume that in this very early maturing population March egg weight was little influenced by age at first egg.

The *medium early maturing group* gave the following constants:

Number of birds	400
Mean age at first egg—days	195.05
Age standard deviation	± 12.17
Mean March egg weight—grams	60.85
Egg weight standard deviation	± 3.78
Coefficient of correlation	− .0748 ± .0335

Only 14 birds in this population of 400 were older than 219 days when they laid their first egg, so that the mean age of the group falls at 195 days. Such a mean value may be considered representative of a population carrying either gene E or gene E' alone (Hays, 1936). March egg weight was heavier than that obtained in the extremely early maturing group, probably owing largely to greater body weight. Regression of egg weight on age at first egg was strictly linear. The coefficient of correlation was negative, but was of such small magnitude as to have no statistical significance.

In general, our data show no relation between age at sexual maturity and the mean weight of eggs laid by pullets at about eleven months of age.

2. *Age at First Egg and Winter Clutch Size*

It seemed desirable to confirm previous observations on Rhode Island Reds that age at sexual maturity is negatively correlated with winter clutch size. Hays and Sanborn (1927a) reported a correlation of −.2273 ± .0103 between age at first egg and winter clutch size. Hays and Sanborn (1927b) found the partial correlation between age at first egg and winter clutch size to be −.1879 ± .0105. Knox, Jull and Quinn (1935) reported no significant correlation between age at first egg and percentage production to March 1 in either Rhode Island Reds or White Leghorns. Lerner and Taylor (1937) found a very low correlation between age at first egg and net winter rate of laying in White Leghorns.

A population of 1470 birds was used in this study, and the following constants were obtained:

Number of birds	1470
Mean age at first egg—days	189.82
Age standard deviation	± 16.43
Mean winter clutch size—eggs	3.23
Clutch size standard deviation	± 1.42
Coefficient of correlation	− .0921 ± .0174
Correlation ratio	.1398

The above data show that the birds used for study were extremely variable in winter clutch size. The standard deviation divided by the mean gives a coefficient of variation of 43.9 percent. Blakeman's test showed that the regression of clutch size on age at first egg was not strictly linear. The correlation ratio .1398, therefore, expresses the association, which is of a negative order and is statistically significant. This correlation is less intimate than was observed in earlier generations but does indicate that earlier maturing females are likely to be more intense layers than later maturing individuals. It should be noted that the population included only 53 birds that matured at 220 days or older.

Relation of Winter Intensity to Egg Weight

3. *Winter Clutch Size and Winter Egg Weight*

Hays (1930b) pointed out that a gene A for small egg size is probably linked with gene I′ for highest intensity. Since that time gene A has been largely eliminated from the flock so that large egg size prevails (Hays, 1944). It may be anticipated, therefore, that high winter intensity will be less intimately correlated with small egg size than in earlier generations of the flock.

A population of 1463 pullets hatched from 1937 to 1942 was tabulated for study, with the following results:

Number of birds	1463
Mean winter clutch size—eggs	3.23
Clutch size standard deviation	± 1.42
Mean winter egg weight—grams	54.96
Egg weight standard deviation	± 3.88
Coefficient of correlation	− .1383 ± .0173

Mean winter egg weight was determined from the weights of all eggs laid from the first pullet egg up to January 1. Regression of egg weight on clutch size was strictly linear. The coefficient of correlation was − .1383 ± .0173. This is a significant though not intimate correlation and shows that rapid laying does tend to reduce egg size.

4. *Mean Winter Clutch Size and March Egg Weight*

It is also desirable to know if winter clutch size is related to March egg weight. Records are available on 612 birds whose eggs were weighed during March. The following constants appeared:

Number of birds	612
Mean winter clutch size—eggs	3.25
Clutch size standard deviation	± 1.31
Mean March egg weight—grams	60.54
Egg weight standard deviation	± 3.95
Coefficient of correlation	− .1219 ± .0269

Regression of egg weight on winter clutch size was linear. The correlation between winter clutch size and March egg weight was − .1219 ± .0269 and is significant. It is apparent, therefore, that in selective breeding for high winter intensity care must be taken to maintain egg size at a satisfactory level.

5. *Mean Winter Clutch Size and Annual Egg Weight*

Annual egg weight as used here represents the mean of twelve monthly means obtained by weighing every egg as taken from the trapnests. Such records are available on 430 females. The following are the constants calculated:

Number of birds	430
Mean winter clutch size—eggs	3.17
Clutch size standard deviation	± 1.33
Mean annual egg weight—grams	58.51
Egg weight standard deviation	± 3.79
Coefficient of correlation	− .0748 ± .0343

The coefficient of correlation is negative but is of such small magnitude as to be insignificant. Regression was strictly linear.

These data indicate that birds may be selectively bred for high winter intensity without influencing mean annual egg weight.

Relation of Egg Production to Egg Weight

6. *Winter Production and Winter Egg Weight*

Winter production of eggs from the first pullet egg up to March 1 is something of a measure of intensity of laying even though it is greatly influenced by age at first egg and by winter pause duration. The number of eggs laid before March 1 may be paired against the mean egg weight up to January 1. This procedure was followed, using 1463 individual pullet records to derive the following constants:

Number of birds	1463
Mean winter production—eggs	91.12
Winter production standard deviation	± 24.98
Mean winter egg weight—grams	54.96
Egg weight standard deviation	± 3.88
Coefficient of correlation	− .1593 ± .0172
Correlation ratio	.1915

The winter egg records of the birds were high, as shown by the mean of 91 eggs, but the variability was great amounting to more than 27 percent. Regression of winter egg weight on winter egg production was not linear so that the correlation ratio .1915 expresses the association. While the association was not intimate, it is significant and shows that egg size up to January first does decline as egg production increases.

7. *Winter Production and March Egg Weight*

Possible association between winter egg production and egg weight during the month of March is important. Records are available on 612 pullets whose eggs were weighed in March. The following constants were derived:

Number of birds	612
Mean winter production—eggs	96.97
Winter production standard deviation	± 26.85
Mean March egg weight—grams	60.54
Egg weight standard deviation	± 3.95
Coefficient of correlation	− .0997 ± .0270

The correlation shown above is low but probably significant. It seems reasonable to assume, therefore, that egg weight during March, the popular month for hatching, is not greatly affected by the number of eggs laid up to March 1.

8. *Winter Production and Annual Egg Weight*

It is desirable to know whether there is a correlation between winter egg production and annual egg weight. Records are available on 430 females from which the following constants were calculated:

Number of birds	430
Mean winter production—eggs	98.10
Winter production standard deviation	± 27.89
Mean annual egg weight—grams	58.51
Egg weight standard deviation	± 3.79
Coefficient of correlation	+ .0004 ± .0325

The mean annual egg weight was 58.51 grams, which is equivalent to 24.8 ounces to the dozen. The population studied evidently carried an inheritance for large egg size along with a relatively low degree of variability. Regression was linear but there was no correlation between winter egg production and annual egg weight in the population studied.

9. *Annual Production and Annual Egg Weight*

Investigators are not in agreement concerning the relation between annual production and mean annual egg weight. Atwood (1928), after rather extensive studies with White Leghorns, concludes that there is no relation between the number of eggs laid and the average size of the eggs. Marble (1930, 1931) made extensive studies on factors affecting egg weight in White Leghorns, Barred Plymouth Rocks, and Rhode Island Reds. He showed that the regression of egg weight on number of eggs was non-linear. By using the correlation ratio he found a significant negative correlation between number and weight of eggs in White Leghorns but not in Barred Plymouth Rocks or Rhode Island Reds.

The present study included 430 Rhode Island Reds upon which the correlation was determined between annual egg production and annual egg weight. The following values were obtained:

Number of birds	430
Mean annual production—eggs	212.59
Production standard deviation	± 42.41
Mean annual egg weight—grams	58.51
Egg weight standard deviation	± 3.79
Coefficient of correlation	+ .0686 ± .0324
Correlation ratio	.2297

A positive correlation of no significant value appeared in the above population of Rhode Island Reds. A test showed that the regression of egg weight on annual production was non-linear. The correlation ratio was .2297, of a positive order and significant. The positive nature of the association is not in agreement with Marble's observations on White Leghorns, and he found no evidence of non-linear regression in the Rhode Island Reds used in his study.

Relation of Winter Production and Intensity to Annual Production

10. *Winter and Annual Egg Production*

Winter egg production has long been used as a criterion of annual production during the first laying year. The fact is also recognized that a correlation between winter and annual production is spurious because the annual egg record includes the winter egg record. In the population studied here mean winter production was 91.10 eggs and mean annual production was 213.57 eggs, giving a large overlapping of records.

In order to avoid this error the correlation was determined between winter production and production for the remainder of the year. The following are the constants:

Number of birds	1470
Mean winter production—eggs	91.10
Winter production standard deviation	± 25.04
Mean subsequent production—eggs	122.55
Subsequent production standard deviation	±34.11
Coefficient of correlation	+ .0607 ± .0175
Correlation ratio	.1770

The variability in production was essentially the same during the winter period and during the period covering the remainder of the year giving a coefficient of variation of about .27. This fact shows that several factors are operating to cause variation in the laying records of both periods. Regression of subsequent production on winter production was non-linear, so that the correlation ratio more properly expresses the association. This constant is positive and significant but as a criterion of subsequent production the winter egg record is of much lower value than the mean winter clutch size, as will appear later.

11. *Winter Clutch Size and Annual Egg Production*

There is no question but that intensity or rate of laying is an important character affecting annual egg production. Attention has already been called to some of the different measures of intensity. Since winter clutch size is generally used here to measure intensity, it is important to know the intimacy of the correlation between winter clutch size and annual egg production. The following constants were determined:

Number of birds	1470
Mean winter clutch size—eggs	3.23
Clutch size standard deviation	± 1.42
Mean annual production—eggs	213.57
Annual production standard deviation	± 43.38
Coefficient of correlation	+ .5011 ± .0132
Correlation ratio	.5603

Regression of annual production on winter clutch size was non-linear. The correlation ratio, therefore, expresses the association. The value .5603 squared indicates that about 31 percent of the variation in annual egg production is due to variation in winter clutch size. The fact stands out clearly that winter clutch size is a most important character affecting annual egg production. The value of the association is considerably higher than that given in an earlier report (Hays and Sanborn, 1927a), where r was .3544 ± .0117.

Inheritance of High Intensity

12. *Correlation between Mothers and Daughters in Winter Clutch Size*

Winter clutch size is one measure of intensity that is inherited, according to Hays and Sanborn (1927a). Other measures of intensity have already been referred to, and the general belief is that rate or intensity of laying is governed by inherited factors. One common test that may be used is the coefficient of correlation. There were available for study 258 mothers that produced 1470 daughters from which the following constants were derived:

Number of dams	258
Number of daughters	1470
Mean winter clutch size of dams—eggs	3.74
Clutch size standard deviation	± 1.64
Mean winter clutch size of daughters—eggs	3.23
Clutch size standard deviation	± 1.42
Coefficient of correlation	+ .1365 ± .0173

The dams were, on the average, superior to their daughters in winter clutch size. Dams and daughters were about equally variable in clutch size. Regression proved to be linear, and the correlation coefficient was .1365 ± .0173, which was barely significant. This fact suggests that the dams were not breeding true for high intensity and that more attention needs to be given to factors concerned in the inheritance of high winter intensity.

Relation of Intensity and Broodiness

13. *Winter Clutch Size in Relation to Broodiness*

Hays and Sanborn (1927a) pointed out that Rhode Island Red pullets that exhibited the broody instinct showed a larger mean winter clutch size than those individuals that showed no evidence of broodiness in the first laying year. Hays (1933) stated that 1188 pullets that showed evidence of broodiness had a mean winter clutch size of 2.96 compared with a mean winter clutch size of 2.50 for 2679 individuals that gave no evidence of broodiness in their first laying year.

The present population included 56 pullets that gave evidence of broodiness in the first year and 1414 pullets that failed to show evidence of broodiness in the first laying year. The mean winter clutch size of the broody birds was 3.81 compared with 3.20 for the non-broody population. The difference, .61, was tested for significance by Fisher's t method. The value of t was 3.09, which indicates that the broody population was definitely superior in winter clutch size. This confirms the previous observation.

Relation between Intensity in Winter and in the Other Seasons

14. *Winter Clutch Size and Spring Clutch Size*

As already indicated, winter clutch size is measured over the period from first pullet egg to March 1. Spring clutch size may be determined for the period March, April, and May, which is the normal hatching season for this area. It is a season when egg production usually stands at a high level and when unimproved hens usually lay eggs. It is important to know whether winter clutch size and spring clutch size are intimately correlated in our high producing birds. In a previous study (Hays and Sanborn, 1932) using lower producing birds, the correlation ratio was found to be .4171, which is rather intimate.

The present population included 1467 birds from which the following constants were derived:

Number of birds	1467
Mean winter clutch size—eggs	3.23
Winter clutch size standard deviation	± 1.42
Mean spring clutch size—eggs	4.04
Spring clutch size standard deviation	± 2.44
Coefficient of correlation	+ .4636 ± .0138
Correlation ratio	.4864

The above data show that even in these superior birds spring clutch size was larger than winter clutch size. In other words, environmental conditions of the spring period, March, April, and May, stimulated the birds to a new high level of intensity, even though they had been laying at a high rate. Regression was found not to be strictly linear so that the correlation ratio more accurately expresses the association between winter clutch size and spring clutch size. The correlation ratio was .4864, and its squared value, .24, indicates that about 24 percent of the variation in spring clutch size is due to variation in winter clutch size. Selection on the basis of large winter clutch size is, therefore, a very good criterion of large spring clutch. These data are in agreement with those of Lerner and Taylor (1937) who found an intimate correlation between winter and spring rate in White Leghorns.

15. *Winter Clutch Size and Summer Clutch Size*

Production during the summer months, June, July and August, is very important in flocks bred for high egg production. Environmental conditions are often far from optimum as far as temperature is concerned. During the season the reproductive system is often depleted following the long period of winter and spring production. In general, birds that show the ability to lay at a high rate in summer are superior for breeding purposes. It is desirable to know whether winter clutch size is a reliable criterion from which to judge the probable summer rate of laying. The coefficient of correlation furnishes a good measure of association and this was determined between winter clutch size and summer clutch size. The following constants appeared:

Number of birds	1458
Mean winter clutch size—eggs	3.23
Winter clutch standard deviation	± 1.42
Mean summer clutch size—eggs	3.06
Summer clutch standard deviation	± 1.68
Coefficient of correlation	+ .3218 ± .0158
Correlation ratio	.3539

The above means indicate that the rate of laying declined in the summer as compared with the winter season. There is also evidence that the variability in clutch size is greater during the summer months. Regression of summer clutch size on winter clutch size was not strictly linear so that the correlation ratio .3539 expresses the association. This is a rather intimate correlation and indicates that large clutch size in winter is likely to persist through the summer.

16. *Winter Clutch Size and Fall Clutch Size*

Birds hatched in March and April usually complete their first 365 days of laying in September or October. In this study the period including September and October is designated as the fall period. Knox, Jull and Quinn (1935) pointed out that the number of eggs laid in August and September at the close of the first laying year was the best measure of persistence in White Leghorns and Rhode Island Reds. They reported the partial correlation between production during these two months and annual production to be + .733 for Leghorns and + .772 for Rhode Island Reds. A high rate of laying in September and October is maintained only by superior birds. It is therefore very important to know whether the mean clutch size of the first winter is a criterion of possible clutch size in September and October at the end of the laying year. The coefficient of correlation was therefore calculated between winter clutch size and fall clutch size, giving the following constants:

Number of birds	1297
Mean winter clutch size—eggs	3.26
Winter clutch standard deviation	± 1.46
Mean fall clutch size—eggs	2.21
Fall clutch standard deviation	± 1.24
Coefficient of correlation	+ .2646 ± .0174
Correlation ratio	.3306

The above records show that intensity was at a low level in September and October. The variability in clutch size was also considerably greater in the fall season. Regression of fall clutch size on winter clutch size was non-linear, but the correlation ratio, .3306, showed an important association between the two.

The data indicate in general that the rate of laying as measured by mean clutch size from first egg to March 1 is a satisfactory criterion of rate of laying throughout the year, and are in agreement with those of Lerner and Taylor (1937), who show that winter rate, spring rate, and summer rate are all correlated with each other.

Summary

This report includes the first-year records of 1470 predigreed Rhode Island Red females bred for high fecundity and hatched over a six-year period from 1937 to 1942. Particular attention is given to the relation of intensity or rate of laying to egg weight and egg production during the first laying year.

Some of the more important deductions from this study follow:

1. Age at first egg showed very little correlation with egg weight during March, either in an extremely early maturing group or in a medium early maturing group.

2. There was a small but significant negative correlation between age at first egg and mean winter clutch size.

3. Winter clutch size (to March 1) showed a small but significant negative correlation with egg weight to January 1, and a moderate negative correlation with March egg weight, but no correlation with annual egg weight.

4. There was a negative correlation between winter egg production (to March 1) and winter egg weight (to January 1), and a small negative correlation between winter egg production and March egg weight; but winter egg production and annual egg weight were independent of each other.

5. The use of the correlation ratio showed that annual egg weight was positively correlated with annual egg production.

6. Winter egg production showed a significant positive correlation with egg production for the remainder of the year.

7. Winter clutch size was intimately correlated with annual production.

8. There was some evidence of inheritance of winter clutch size between mothers and daughters.

9. Winter clutch size was significantly greater in broody than in non-broody individuals.

10. Winter clutch size was significantly correlated with spring, summer, and fall clutch size.

11. These data furnished rather substantial evidence that winter clutch size is one of the more reliable measures of intensity and that it is one of the most important characters associated with egg production.

References

Atwood, Horace. 1923. Certain correlations in the weight and number of eggs and the weight of fowls. W. Va. Agr. Expt. Sta. Bul. 182.

Atwood, Horace. 1928. Certain normal characteristics of White Leghorn females. W. Va. Agr. Expt. Sta. Bul. 220.

Dryden, James. 1921. Egg laying characteristics of the hen. Oreg. Agr. Expt. Sta. Bul. 180.

Goodale, H. D. 1918. Internal factors influencing egg production in the Rhode Island Red breed of domestic fowl. Amer. Nat. 52:65-94, 209-232, and 301-321.

Hays, F. A. 1924. Inbreeding the Rhode Island Red fowl with special reference to winter egg production. Amer. Nat. 58:43-59.

Hays, F. A. 1930a. Increase in egg weight during the pullet laying year. Proc. Poultry Sci. Assoc. 1930, pp. 16-19.

Hays, F. A. 1930b. Linkage relations between genes for egg size and genes concerned in high fecundity in domestic fowl. Proc. Fourth World's Poultry Cong. pp. 134-138.

Hays, F. A. 1933. Characteristics of non-broody and intense broody lines of Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 301.

Hays, F. A. 1934. Time interval from first egg to standard egg weight in Rhode Island Red pullets. Mass. Agr. Expt. Sta. Bul. 313.

Hays, F. A. 1936. Inheritance of sexual maturity in Rhode Island Reds. Proc. Sixth World's Poultry Cong. pp. 34-38.

Hays, F. A. 1944. Variability in egg weight in Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 411.

Hays, F. A., and Ruby Sanborn. 1927a. Intensity or rate of laying in relation to fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 11.

Hays, F. A., and Ruby Sanborn. 1927b. Net correlations of characters concerned in fecundity. Mass. Agr. Expt. Sta. Tech. Bul. 12.

Hays, F. A., and Ruby Sanborn. 1932. Types of intensity in Rhode Island Reds. Mass. Agr. Expt. Sta. Bul. 286.

Hurst, C. C. 1921. The genetics of egg production in White Leghorns and White Wyandottes. Natl. Poultry Jour. 2, Sept. 2 to Dec. 9.

Jull, M. A. 1940. Poultry Breeding, p. 313. John Wiley and Sons, New York.

Knox, C. W., M. A. Jull, and J. P. Quinn. 1935. Correlation studies of egg production and possible genetic interpretations. Jour. Agr. Res. 50 (7):573-589.

Lerner, I. M., and L. W. Taylor. 1936. The relation of pause to rate of egg production. Jour. Agr. Res. 52:39-47.

Lerner, I. M., and L. W. Taylor. 1937. Relationships of egg production factors as determined for White Leghorn pullets. Jour. Agr. Res. 55 (9):703-712.

Marble, D. R. 1930. The non-linear relationship of egg weight and annual production. Poultry Sci. 9 (4):257-265.

Marble, D. R. 1931. A statistical study of factors affecting egg weight in the domestic fowl. Poultry Sci. 10 (2):84-92.

Pearl, Raymond. 1912. The mode of inheritance of fecundity in domestic fowl. Jour. Expt. Zool. 13 (2):153-268.

Taylor, L. W., and I. M. Lerner. 1938. Breeding for egg production. Calif. Agr. Expt. Sta. Bul. 626.

Tomhave, A. E. 1941. Intensity of fall and winter egg production of pullet progeny sired by cockerels sib-tested for intensity of production. Del. Agr. Expt. Sta. Bul. 232.

Publication of this Document Approved by Commission on Administration and Finance
4m (a) 7-44-14630

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 417 AUGUST 1944

Annual Report

For the Period Ending June 30, 1944

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

Trustee Committee on Experiment Station

	Term Expires
Malcolm, David J., Charlemont, *Chairman*	1946
Webster, Louis A., *Acting Commissioner of Agriculture*	
McNamara, Mrs. Elizabeth L., Cambridge	1944
Hubbard, Clifford C., Norton	1946
Whitmore, Philip F., Sunderland	1948
Brett, Alden C., Watertown	1950

Experiment Station Staff, June 30, 1944

Hugh P. Baker, President of the College

Sievers, Fred J., Director
Gaskill, Edwin F., Assistant to the Director
O'Donnell, Margaret H., Secretary

Hawley, Robert D., Treasurer
Felton, F. Ethel, Editor
, Technical Assistant

*Alexander, Charles P., Entomology
Archibald, John G., Animal Husbandry
Bourne, Arthur I., Entomology
*Bradley, Leon A., Bacteriology
Colby, William G., Agronomy
Doran, William L., Botany
*Eisenmenger, Walter S., Agronomy
¶*Fellers, Carl R., Food Technology
*Frandsen, Julius H., Dairy Industry
†*Franklin, Henry J., Cranberries
¶Freeman, Monroe E., Chemistry
Fuller, James E., Bacteriology
*Gamble, Philip L., Economics
*Gaskill, Edwin F., Station Service
*Griffiths, Francis P., Food Technology
‡Guba, Emil F., Botany
*Gunness, Christian I., Engineering
Haskins, Henri D., Agricultural Chemistry (Professor Emeritus)
Hays, Frank A., Poultry Husbandry
*Holdsworth, Robert P., Forestry
Holland, Edward B., Chemistry (Professor Emeritus)
Holmes, Arthur D., Chemistry
*Holmes, Julia O., Home Economics Nutrition
Kightlinger, Clifford V., Agronomy
‡*Koon, Ray M., Horticulture
*Lentz, John B., Veterinary Science
*Lindsey, Adrian H., Agricultural Economics and Farm Management
McKenzie, Malcolm A., Botany
Morse, Fred W., Chemistry (Professor Emeritus)
¶Olson, Carl, Jr., Veterinary Science
*Osmun, A. Vincent, Botany
*Parkhurst, Raymond T., Poultry Husbandry
*Rice, Victor A., Animal Husbandry
*Ritchie, Walter S., Chemistry
Rozman, David, Economics
Shaw, Jacob K., Pomology
¶Sieling, Dale H., Chemistry
*Smith, Philip H., Dairy, Feed, Fertilizer, and Seed Laws
*Snyder, Grant B., Olericulture
*Thayer, Clark L., Floriculture
*Van Meter, Ralph A., Pomology
Van Roekel, Henry, Veterinary Science
‡Whitcomb, Warren D., Entomology
Wood, Basil B., Library

Bailey, John S., Pomology
Bennett, Emmett, Chemistry
Brown, Alfred A., Agricultural Economics and Farm Management
Bullis, Kenneth L., Veterinary Science
Creek, Charles R., Agricultural Economics and Farm Management
¶†Cross, Chester E., Cranberries
‡Dempsey, Paul W., Horticulture
¶DeRose, H. Robert, Feed and Fertilizer Laws
Esselen, William B., Jr., Food Technology
Flint, Oliver S., Veterinary Science
¶France, Ralph L., Bacteriology
‡Gilgut, Constantine J., Nurseryculture
Gutowska, Marie S., Nutrition
Jones, Carleton P., Chemistry
Jones, Linus H., Botany
Kuzmeski, John W., Feed and Fertilizer Laws
¶Levine, Arthur S., Food Technology
McLaughlin, Frederick A., Seed Law
Mueller, William S., Dairy Industry
Smith, C. Tyson, Feed and Fertilizer Laws
Spelman, Albert F., Feed and Fertilizer Laws
Wertz, Anne W., Home Economics Nutrition
‡White, Harold E., Floriculture
‡Young, Robert E., Olericulture

Anderson, Jessie L., Seed Law
Becker, William B., Entomology
¶‡Bemben, Peter, Olericulture
¶‡Bobula, Paul, Nurseryculture
Clarke, Miriam K., Veterinary Science

‡Conlon, Mary E., Olericulture

Crosby, Earle B., Veterinary Science
¶Crowley, Leo V., Feed and Fertilizer Laws
¶‡Donnelly, Edward B., Floriculture
‡Garland, William, Entomology
Harlow, William, Poultry Husbandry
Howard, James T., Dairy, Feed, and Fertilizer Laws
Jewett, Felicia, Veterinary Science
†Kelley, Joseph L., Cranberries
Kucinski, Karol J., Agronomy
Martell, Joseph A., Dairy, Feed, and Fertilizer Laws
McConnell, John E. W., Food Technology
Miller, Elaine P., Agricultural Economics and Farm Management
Miner, Gladys I., Botany
Parkinson, Leonard R., Home Economics Nutrition
Rodman, Henry B., Feed and Fertilizer Laws.
Sanborn, Ruby, Poultry Husbandry
Sherburne, Ruth E., Economics
Southwick, Lawrence, Pomology
Spear, Arthur J., Home Economics Nutrition
‡Tomlinson, William E., Jr., Entomology
White, W. Henry, Botany
‡Wilson, Harold A., Horticulture
Yegian, Hrant M., Agronomy
‡Young, Helen, Floriculture
Zatyrka, Irene E., Pomology

---

*In charge †At East Wareham ‡At Waltham ¶On Military Leave.

CONTENTS

Page

Agricultural Economics and Farm Management 4

Agronomy 6

Animal Husbandry 14

Bacteriology 16

Botany 18

Chemistry 24

Control Services 27

The Cranberry Station 28

Dairy Industry 30

Economics 32

Engineering 32

Entomology 33

Floriculture 44

Food Technology 45

Home Economics Nutrition 49

Horticulture 53

Olericulture 54

Pomology 56

Poultry Husbandry 64

Veterinary Science 68

Waltham Field Station 71

Publications 72

ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1943-44

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Effect of Public Regulation of Milk Marketing upon the Organization of Milksheds of Massachusetts Markets. (A. A. Brown.) Programs developed as wartime measures by various Federal agencies currently overshadow the effect of local marketing regulations. Except as the prestige of pre-war institutions is brought to the support of the War Food Administration, Office of Price Administration, or Office of Defense Transportation, their influence is dormant.

Data are being assembled as they become available on (1) the efforts of the War Food Administration to maintain and stimulate milk production with feed subsidies; and (2) the efforts of the Office of Price Administration to maintain milk consumption through the establishment of ceiling prices on sales at retail and wholesale.

Conflicting forces are present in various programs; forces which in the long run may prove to be very detrimental to the public interest. Shortages in labor, materials, and equipment, now faced by the industry as a result of the concentration of resources to war purposes, would normally result in the development of efficiencies. Some of these are coming but in a way which it was hoped might be avoided. Greater efficiency in city distribution has long been sought. Operations were multiplied along the lines of an "industrial make-work" program. Order could have been brought out of this turbulent operation through more positive public control or through concentration by the industry. The larger elements appear to be absorbing the smaller ones or the weaker ones.

The number of handlers in Boston in May 1944 was 284 compared with a 1938–1940 three-year average of 441. All group handlers, handler–buyers and producer–handlers showed approximately uniform numerical reductions of 49-59, although the handler group had the greatest proportionate reduction of 40 percent.

Similar changes are also shown for the Lowell-Lawrence market although differences in reports do not permit precise monthly comparisons. In this market for the month of April the total number has declined from 232 in 1941 to 158 in 1944. Producer–handlers dropped most from 111 to 69; a reduction of 37 percent. Other markets in the state are undergoing similar changes. Tabulations of these have not yet been made.

Rulings of the OPA and ODT are in conflict on the matter of milk trucking charges in the country; one prohibits reductions; the other, increases (as a result of conservation measures). With charges frozen, one of the strongest inducements toward the efficient use of trucking in the country is eliminated.

Transportation Requirements of Rural Communities in Massachusetts. (A. A. Brown.) Attention has been concentrated under the study towards the development of truck conservation programs in the dairy field.

Studies of operations have been completed in four major markets: Worcester, Boston, Brockton, and Fitchburg. Studies are continuing in Springfield and Lowell–Lawrence.

As a result of these studies and the recommendations developed therefrom, daily savings in mileage for four cities now approximate 1329 or 8.4 percent. The range is from 3.9 percent in the Boston market to 25.8 in Brockton.

The Development of Statistical Data as Controls to Livestock Production Programs. (A. A. Brown.) Development of the sample areas has been completed for the State. Attention is now being focused on the usefulness of the square mile grids as a means of sampling Massachusetts agriculture. In Hampshire County where the checking is nearing completion, there appears to be some doubt as to the uniform relationship between land distribution and farm distribution.

Organization and Management of Poultry Farms in Massachusetts. (C. R. Creek.) Poultry farming was more profitable in Massachusetts in 1943 than in any of the previous four years, according to the summary of Poultry Account Records. For the farms reporting, net farm income averaged $3660 per farm, which was 53 percent greater than in 1942, double the return in 1941, more than three times greater than in 1940, and two and one-half times greater than in 1939. The size of the laying flock was about 750 birds each year, but the type of business has changed. The proportion of cash receipts from the sale of hatching eggs, chicks, and pullets has more than doubled in the past two years over 1939 and 1940. Some increase was noted in broiler sales in 1943. Other factors responsible for increased returns were higher egg production per hen, much higher prices for eggs in 1942 and 1943, and a more favorable feed–egg ratio because of these higher prices.

The one-third of the farms most profitable in 1943 earned net farm incomes of $6740 per farm, while the one-third least profitable earned only $940 per farm. Some of the reasons for the higher net incomes are: size of business three times greater, a greater proportion of cash receipts from hatching eggs and chicks, an average production of 44 more eggs per hen, 7.5 cents a dozen higher price received for eggs, 4 cents per dozen lower cost of feed, 1.5 less dozens of eggs required to purchase 100 pounds of feed for the laying flock, and more efficient use of labor.

Records for 21 identical poultry farms for 1942 and 1943 showed average net farm incomes of $2530 and $3685. The more important reasons for the higher returns in 1943 were: an increase of 12 cents per dozen in average price received for eggs, an increase of 56 percent in sales of broilers, an increase of 112 percent in sales of chicks and pullets, an increase of 67 percent in sales of hatching eggs, a more favorable feed–egg ratio, and more work accomplished with less months of labor.

Labor Saving Methods and Practices on Massachusetts Farms. (C. R. Creek.) Studies made during the 1943 season on Iceberg lettuce indicated that a 3-man harvesting crew (2 men cutting and 1 packing into crates) was the most efficient, fastest, and least fatiguing method of field harvesting. In the packing shed a 6 to 8 man crew operating a "line-system" for washing, icing, fastening crates, and loading crates was the most efficient. Output in crates per man per hour was highest and the work was much less fatiguing than by other methods where the crates were lifted and carried back and forth several times during the packing shed operations.

The "line-system" was used in harvesting broccoli in the field as well as in the packing shed operations on a farm where all work was accomplished with a minimum of effort and high output per man. The broccoli was lifted from the ground once (when cut). Tables and roller conveyors were used to eliminate lifting and carrying in the packing shed. Bunching of the broccoli was paid for on a piece work basis at a favorable rate and the work was done more quickly because of this incentive pay.

Loan Performance on Low Income Farms in Massachusetts. (C. R. Creek.) Through December 1943, loans had been repaid in full for 42 out of 92 cash-crop loans made since 1936 by the Farm Security Administration in the three Connecticut Valley counties of Massachusetts. Payments were generally made in large amounts from the sale of onions, potatoes, or tobacco. Two years (1942 and 1943) of good yields and high prices enabled these crop farmers to pay off delinquent loans as well as the 1943 operating loan. Total loans were $2345 per farm for a period of 1 to 7 years' duration and the average loan was $938 annually. Interest on the loans which were paid amounted to $72 per loan. The average length of these crop loans that had been repaid was about 1.5 years.

Loans on livestock-crop farming units were made on 74 diversified farms from 1936 through 1943 and 40 had been repaid by the end of the latter year. These loans were generally repaid in small monthly installments from the sale of milk and eggs. Larger payments were made occasionally from sales of crops, cattle, or poultry. Auctions of livestock and equipment on dairy and poultry farms were necessary to close delinquent loans on one-fourth of the farms. Five borrowers had ceased to operate their farms since 1941 and had made large payments through the sale of livestock and farm machinery. These loans were finally closed by payments from wages earned in industrial employment. Sales of crops and livestock products were used to repay the remainder of the loans. Total loans were $1358 per farm for a period of 2 to 7 years and the average size of loan was $823 annually. Interest on the loans which were repaid amounted to $61 per loan. The average length of these loans was about 2.5 years.

Repayment of loans has been more satisfactory on the cash crop farms than on those farms having livestock enterprises. Crop losses from floods, frost, and hail have prevented some crop farmers from paying off their loans, but most of the delinquent livestock loans were due to poor management.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karel J. Kucinski.)

Brown Root Rot of Tobacco. The experiment was designed to determine the effect of the preceding crop on the yield and crop index of tobacco. The various preceding crops were planted at three different times during the season. The earliest matured completely; the two others did not mature. All were plowed under in the spring after the tops had been almost completely dehydrated by natural freezing, thawing, and drying. Those crops which had matured completely and contained a high percentage of fiber in the vegetative tissue reacted unfavorably to the tobacco crop.

The amount of material to be plowed under was not an index of the yield or quality of tobacco. Sunflowers and Jerusalem artichokes afforded abundant material to be turned under; yet the tobacco crops after these plants were among the best.

Crops such as sunflower, artichoke, tobacco, and fallow might be classified as the better preceding crops for tobacco; buckwheat, barley, rape, millet, wheat, and rye are less satisfactory; and such crops as corn, oats, sudan grass, and sorghum are consistently unfavorable when used in rotation with tobacco.

Black Root Rot of Tobacco. (C. V. Kightlinger.) Several strains of Havana Seed have been produced which are capable of producing high yields of tobacco of superior type and quality in soils infested with the organism that causes black root rot as well as in soils free from diseases. Havana Seed 211 is the best of the strains that have been tested thoroughly, but it is not entirely acceptable to all cigar manufacturers. In spite of this fact, this strain is grown in large acreage in the Connecticut Valley and has been an important factor in increasing the average yield per acre and in improving the quality of Havana Seed tobacco produced in the Valley during the last several years.

New strains of Havana Seed are being produced, some of which seem to possess improvements in type, quality, and habits of growth, especially in leaf conformation and in earlier maturity. Two of these strains are being tested in commercial production, and also in the manufacture of cigars by leaders in the business.

Brown Root Rot of Tobacco. (C. V. Kightlinger.) Since brown root rot often develops on tobacco following other crops, one phase of this study is concerned with the growing of a number of crops deleterious to succeeding crops of tobacco, to see whether unusually large applications of fertilizer will reduce the occurrence and severity of brown root rot on following crops of tobacco.

The other phase of the work is a study of tobacco grown continuously, to see whether brown root rot can be produced by a low state of fertility and then to study the possible corrective effect of different fertilizing materials.

It has taken several years to accomplish the preliminary work of getting the soil into the desired condition for a study of the main objective of the project—how low fertility of soil and inadequate fertilization affect the development not only of brown root rot of tobacco, but also of root ailments of several other farm crops.

Disinfection of Tobacco Seedbeds. (C. V. Kightlinger.) Fall treatments with chloropicrin and calcium cyanamid used singly and in combination, fall and spring steaming, and fall and spring treatments with formaldehyde were used. No noticeable damping-off, bed-rot, or other root diseases of tobacco seedlings occurred in the seedbeds during the season; therefore no definite information could be obtained from this year's experiment about the value of any of the soil treatments as disease control measures.

The spring steamed and the calcium cyanamid treated areas could not be kept moist enough for satisfactory growth of tobacco seedlings because of a temporary change in physical condition of the soil due to the treatments. A further difficulty on the calcium cyanamid treated areas was an accumulation of residual substances on and near the surface of the soil, which seemed to be harmful to tobacco seedlings.

Tobacco seedlings grew much more vigorously in the fall steamed and the chloropicrin treated areas and somewhat more vigorously in the formaldehyde treated areas than they did in the untreated areas. If this was due entirely, or even in large part, to the control of disease, then very slight infections of root diseases retard the growth of tobacco seedlings much more than is generally recognized. It is reasonable to believe, however, that these treatments had other invigorating effects on plant growth besides the control of diseases.

Fall steaming and chloropicrin treatments were highly effective in the control of weeds in the seedbeds, the fall steaming being somewhat more effective. Formaldehyde gave only slight control of weeds. No weeds grew in the spring steamed and the calcium cyanamid treated areas at any time during the season.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Karol J. Kucinski.) When the individual ions were applied to the soil at the rate of 200 p.p.m., the percentage intake by plants was greater for magnesium, sodium, and potassium than for calcium. Chlorine, bromine, and iodine intake was higher than the intake of phosphorus or sulfur when equal parts per million were added to the soil.

The place of the plant in the evolutionary scale, as well as the individual ion, is a factor in the increased intake. A more highly developed plant — lettuce — did not increase its content of calcium, magnesium, sodium, and potassium as much as did those lower in the evolutionary scale —celery, beets, cabbage, and beans — when the respective ions were added equally to the soil.

The Intake by Plants of Elements Applied to the Soil in Pairs Compared to the Intake of the Same Elements Applied Singly. (Walter S. Eisenmenger and Karol J. Kucinski.) In nearly all cases when two cations were added to a plot, each at the rate of 250 p.p.m., the intake of the ions was depressed in comparison with the intake when each was added singly at the same rate. The intake of two ions added in pairs complicates the interpretation. It is probable that, when there is relative abundance of one ion and little of another, the plant takes more of the abundant ion than is necessary for metabolism. It has even been suggested that one element may regulate the semi-permeable membrane of the plant.

From a practical point of view, it has been observed that liberal potassium applications may lead to magnesium deficiency in plants.

Magnesium Requirements of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) Numerous plants of different botanical families have been grown on a plot, part of which is low in magnesium. Enough magnesium is present in the so-called magnesium-deficient soil to produce normal growth of some plants, but not of others.

Preliminary work suggests that the less evolutionally developed flowering plants need more magnesium in their growing medium than do the plants in the higher orders. No plants of the families Compositae, Chenopodiaceae, Amaranthaceae, or Labiatae and only one member of the family Gramineae have shown deficiency. All of the lower families have shown deficiency to a marked degree, among these being Ranunculaceae, Magnoliaceae, Ulmaceae, Malvaceae, Geraniaceae, Rosaceae, and others.

It would seem that, as far as needs for normal growth are concerned, magnesium is an older element than calcium.

Long-Time Field Fertility Tests. (Walter S. Eisenmenger and Karol J. Kucinski.) About fifty-five years ago a series of so-called soil test plots was inaugurated to study the effects on the soil and crops of a long-time fertilizer program. Various types of crops have been grown on these plots but the original system of fertilization has always been followed, including check plots which have been left unfertilized during the entire period. Recent results, with hay as an indicator crop, showed that the fertility level of all the plots was much higher on the limed than on the unlimed portions. The unlimed portions of the check plots showed crop failure and indications of nutrient deficiencies. On the complete fertilizer plot (N.P.K.), the limed area yielded about 200 percent more hay than the unlimed area. On the limed areas, the complete-fertilizer plot yielded about 50 percent more hay than the no-fertilizer plots. On the unlimed area, the plots receiving nitrogen, nitrogen plus phosphorus, and nitrogen plus potash showed an increase of about 350 percent in yield of hay over the no-fertilizer plots.

Soil Conservation Research Projects. (Karol J. Kucinski and Walter S. Eisenmenger.)

Physical and Chemical Properties of Wind-Blown Soils. During the past year laboratory tests and field observations were made to determine why certain soils are subject to wind erosion while others are not. The chemical and physical properties of the various soils were studied intensively to see whether there is any correlation between these properties and wind erodibility. A wind tunnel especially designed for local conditions has been used to supplement field observations.

It has been found that certain Connecticut Valley soils will erode at as low a wind velocity as four miles per hour, while others will not blow at much higher velocities. Most soils tested will seriously erode at wind velocities varying from 15 to 20 miles per hour. All the soils tested will blow at 35 miles per hour, except when moist. However, soils containing as much as 25 to 35 percent moisture will blow when frozen since freezing, by solidifying the water molecule, acts as a dehydrating agent. Because there was so little snow in the Valley last season, more dust storms than usual occurred during late fall, winter, and early spring. Chemical treatment of soil with such compounds as urea and lithium carbonate has greatly decreased its wind erodibility.

Use of Snow Fencing in Controlling Wind Erosion. On farms where wind erosion is a problem, it often happens that certain local areas or spots are much more subject to blowing than the remainder of the field. This condition may arise from a variety of causes and usually appears spasmodically in different years or under certain weather conditions. It is recognized that anything that can be used to check the velocity of the wind will have a very definite effect on wind erosion, and highway snow fencing equipment is being studied for use in this connection.

Erosion Problems Arising from Changes in Land Use. Because of the favorable economic position that potatoes have assumed in recent years, many areas that are not particularly suitable for the growing of cultivated crops have been plowed up, with the result that soil erosion problems have been developed that are deserving of serious consideration. Sheet and gully erosion are increasing yearly on some of these fields, and laboratory tests show a yearly increase in the rate of organic matter depletion. Some operators are already experiencing a decrease in potato yields and have called on the Soil Conservation Service for aid in formulating plans for the protection of their fields.

Sunflowers and Their Possibilities. (Karol J. Kucinski and Walter S. Eisenmenger.) Tests show that sunflowers will grow on any land which will grow corn, best results being obtained when the seed was sown, one every 18 inches in 36 inch rows, using corn fertilizer. Sunflowers are more hardy to light frost than corn and can be planted at the time it is safe to plant field corn. Depending on the season and variety, a growing period of 120 to 140 days is sufficient for maturing the seed in Massachusetts. Yields of one to two tons can easily be obtained under favorable conditions.

Onion Breeding. (Hrant M. Yegian.) F_2 progenies from a cross between White Persian, with light leaf color, and Ebenezer, with yellow skin and dark leaf color, gave a close ratio of three yellow to one white skin bulbs. Dark leaf color was dominant over light. There was an extreme variation in leaf color in the F_2 population indicating that this is a quantitative character influenced by the environment.

Storage temperature had a marked effect upon the keeping quality of the bulbs, the subsequent seed stalk development, and the amount of seed produced. Bulbs stored at 32° F. had only 2 percent soft rot, while 15 percent of the bulbs stored at 45° and 59 percent of those stored at 70° had soft rot.

Bulbs stored at 32°F. had a higher percentage of two and three seed stalks and as a group produced more seed than those stored at 45°. On an individual plant basis, however, bulbs stored at 45° produced about 0.23 grams more seed. Only 30 percent of those stored at 70° had seed stalks and these did not produce any seed. On the basis of a two years' record it is therefore recommended that onions be stored in a well-ventilated storage building at 32° at a low humidity.

Onions topped short immediately after pulling had 21 percent rot and those cured for a few days had 22.5 percent; while onions topped long immediately after pulling had 10 percent and those cured for a few days 7.5 percent rot. These onions were stored from July 21 to March 27 in a room which had heating facilities but no cooling system to prevent the rise of temperature on warm days.

Ryegrass as a Green Manure Crop. (Hrant M. Yegian.) The lack of organic matter in most of the onion fields in the Connecticut Valley is one of the serious problems facing the growers. In order to demonstrate that it is practicable to grow green manure crops after the set onions have been harvested and to show their relative value, domestic ryegrass, winter rye, oats, and Japanese millet were seeded on an onion field in Sunderland, Massachusetts, on July 27, 1943, after the onion crop had been harvested.

Domestic ryegrass was by far the best green manure crop because it made a rapid top growth and had a very extensive root system. Winter rye was second best.

A small section of ryegrass was left unplowed in the fall. The spring was late; consequently plowing of this strip was delayed, and it was not in as good a condition at planting time as the fall-plowed section. Because of the possibilities of a late spring it is, therefore, desirable to plow under green manure crops on onion fields in the fall, notwithstanding the fact that fall plowing will not give as good protection against soil erosion from wind or rapid run-off of rain.

Corn Improvement Program. (Hrant M. Yegian.) Ninety-one single crosses involving all possible combinations of fourteen inbreds were tested at this station, in cooperation with the corn breeding program at the Connecticut Agricultural Experiment Station under the direction of Dr. D. F. Jones, in order to determine the most valuable inbreds and to predict the most effective double cross combinations for this area.

An early hybrid produced by the double cross of four inbred lines, Wisconsin (CC4 x CC8) X Quebec (83 x 9), gave very satisfactory yields in 1942 and 1943. More extensive tests are being made in 1944.

A number of hybrids were tested for their general adaptability and yield, and the following are recommended on the basis of previous trials as well as the results obtained in 1943.

Very early hybrids for grain: Maine B, Wisconsin 240 and 255.
Early hybrids: Minnesota 800, 700, and 702.
Medium early hybrids: Wisconsin 355, Minnesota 602, and Cornell 29-3.
Late hybrids: Ohio M-15, DeKalb 201, Iowa 939, Ohio K24 and W46.
Silage corn, in the order of their relative maturity, beginning with the earliest: Cornell 29-3, Wood V20, Iowa 939, N.J. No. 2, Indiana 608A, U.S. 44, U.S. 13, Ohio C 92, and Wood hybrid yellow sweepstakes S. M.

Influence of Soil Fertility on Productiveness of Pasture Species. (Hrant M. Yegian.) The data collected in 1943 and the spring of 1944 substantiated results obtained during the preceding two years. All the species continued to respond to increases in soil fertility. Plots receiving an annual application of 600 pounds of 5–8–7 in April and June and 400 pounds in August consistently produced more grass than plots receiving 400 pounds of 5–8–7 in April and June or only one application in April.

The response to fertilizer was more pronounced during the prolonged dry weather in the spring of 1942 and 1944. Kentucky bluegrass, timothy, and redtop suffered more during periods of drought than meadow foxtail, reed canary grass, orchard grass, or smooth brome grass.

The effect of temperature upon growth varied with different grasses. Kentucky bluegrass, orchard grass, meadow foxtail, and reed canary grass grew almost as well in summer as in spring, provided there was sufficient moisture throughout the growing period.

Orchard grass, Kentucky bluegrass, and reed canary grass made rapid recovery after cutting.

Some of the grasses were non-persistent, especially at a high level of soil fertility. Perennial ryegrass was winterkilled during the winter of 1941–42, and orchard grass, meadow fescue, and rough-stalked meadow grass during the winter of 1943–44. Timothy began to thin out after the third year.

A few of the grasses made more rapid growth in the spring than others. On the first of May, 1944, reed canary grass was eleven inches tall, smooth brome grass six inches, and foxtail five inches; while redtop, Kentucky bluegrass, timothy, fowl bluegrass, and colonial bent were only three inches tall.

Redtop and fowl bluegrass gave as high a yield the first harvest year as the second and the third year; timothy produced most the second year and meadow fescue, orchard grass, and meadow foxtail, the first year; while reed canary grass, smooth brome grass, and Kentucky bluegrass gave their highest yield in the third year.

The fact that most of the species differ from each other in one or more important agronomic characteristics suggests the use of several of these well-adapted species on a farm in order to insure, through a proper scheme of management and soil fertility, a satisfactory and uniformly distributed feed supply throughout the season.

Experiments at Amherst with Hay and Pasture Seeding Mixtures. (W. G. Colby.) Additional data were obtained from a series of plots planted in 1940 with different hay and pasture seeding mixtures. Details of the layout of the experiment were given in a previous report (Mass. Agr. Exp. Sta. Bul. 388:14-15, 1942).

Most of the seed mixtures included in this experiment were simple ones in which one grass was seeded with ladino clover alone or with ladino clover and alfalfa. Except for the first and second years in the plots first cut for hay, alfalfa has not been an important constituent in any of the mixtures. The failure of alfalfa to become established in the pasture series and to persist in the hay–pasture series can probably be attributed to the system of grazing management which was followed.

During the first grazing season (1941) the pasture series was grazed rotationally five times. Under this heavy system of grazing only weak stands of alfalfa were established and these were lost during the following winter. In the plots first cut for hay, the alfalfa was well established before the hay was cut and a good stand was obtained in all alfalfa seedings. However after a crop of hay had been harvested, these plots were also grazed rotationally three times each season. The heavy grazing following the removal of a crop of hay so weakened the alfalfa that most of it had disappeared by the beginning of the third season. If grazing had been restricted to one or two light grazings or if a second crop of hay, only, had been taken, alfalfa would undoubtedly have persisted much longer. Under conditions as they exist at Amherst, alfalfa is a better hay plant than a pasture plant. If alfalfa is used for pasture, cutting the first crop for hay and lightly grazing the second crop is probably the most satisfactory system of management.

By 1943, the third harvest year, wide variations were evident in the proportion of grass to ladino in the different seeding mixtures. The following grasses had eliminated most of the ladino clover: Tall fescue, orchard grass, and Kentucky bluegrass. Redtop provided strong competition but did not eliminate the clover. The most serious competitor to the ladino clover was Kentucky bluegrass. This grass appeared in all plots during the third season, whether seeded or not, with the exception of those with good stands of orchard grass or tall fescue. There was a greater proportion of bluegrass in the plots which were grazed than in those which were cut for hay and then grazed. Observations in the field together with the results of these experiments indicate rather definitely that it is neither necessary nor even desirable to include Kentucky bluegrass in a pasture seeding mixture except where the rapid establishment of a bluegrass sod is desired. To sow bluegrass with ladino clover merely reduces the effectiveness and shortens the life of the clover.

Grasses which persisted but which did not crowd out the clover were smooth brome grass (Canadian strain), meadow fescue (Svalof's early), pasture strains of orchard grass S26, S37, and S143, and perennial rye grass (O.A.C. No. I). The smooth brome–ladino mixture continued to be one of the best mixtures in the experiment. It was the most palatable; yields were good, particularly during midsummer, and a satisfactory clover–grass composition was maintained at all times. By the end of the summer about 60 percent of the herbage was clover and 40 percent grass. Some bluegrass was present in addition to the smooth brome.

Timothy was the only grass included in the experiment which tended to be suppressed by the ladino clover. After the second grazing period in June, timothy made very little growth until cool weather in the late summer and fall.

Response of Different Hay and Pasture Seeding Mixtures to Heavy Nitrogen Fertilization. (W. G. Colby.) In the early spring of 1943, nitrate of soda was applied at the rate of 450 pounds per acre to half of each plot in the series with different seeding mixtures. These plots, seeded in the summer of 1940, made it possible to study the effect of liberal nitrogen fertilization on a number of the more important pasture grasses, both in stands made up largely of grass and also in stands with varying amounts of clover, chiefly ladino. The following results are of interest.

Rate of Application: For conditions as they existed, 450 pounds of nitrate of soda supplied too much nitrogen for best results. The weather during the spring months, particularly May, was much wetter than usual, so that the growth response was abnormally large. Serious lodging occurred in many of the hay plots, and in several of the pasture plots feed was produced for a time faster than it could be efficiently utilized. Under the circumstances, it is probable that 50 pounds of elemental nitrogen to the acre would have been more satisfactory than 75 pounds. Lodging in the hay plots smothered out most of the clover.

Dry Matter Yields: The first harvest on the pasture plots was made on May 27. Increases in yields as a result of nitrogen fertilization varied from no increase in the case of a poor stand of perennial rye grass and ladino clover, to more than two and one-half times increase in yield from a practically pure stand of timothy. The average increase in yield from applied nitrogen for the nineteen different seedings was about 50 percent.

For the second harvest, on June 29, yields of the nitrogen half of the plots varied from a 22 percent decrease for the redtop-ladino clover plot to a 78 percent increase for a practically pure timothy stand. The average increase for all plots was 5.4 percent. The decrease in yield in the case of redtop is explained by the fact that the clover population was greatly reduced in the fertilized half of the plot. In the no-treatment half of the plot, where there was a fairly good stand of clover, yields were well maintained throughout the season. The results obtained at the time of the third harvest, on July 30, were similar to those obtained for the second. Of the increase in yield from additional nitrogen during the season, 94 percent was obtained at the first harvest date in May.

Response of Different Grasses: Timothy gave the greatest response to nitrogen fertilization, followed in turn by smooth brome grass, Kentucky bluegrass, redtop, meadow fescue, perennial rye grass, and orchard grass. The average increase in yield for four different strains of timothy (fairly pure stands) was 82.6 percent for the first harvest, 28.1 percent for the second, and 4.9 percent for the third.

Effect of Nitrogen on the Clover Population: The effect of nitrogen on the clover population varied greatly with different grasses. When redtop was present to an appreciable extent, additional nitrogen tended to strongly suppress the clover. For example, a redtop-ladino clover plot was made up of 80 percent redtop and 20 percent clover in the spring. By fall the nitrogen half of the plot had only 10 percent clover, while the untreated half contained 60 percent clover. Kentucky bluegrass reacted similarly to redtop.

Tall fescue and orchard grass had already crowded out much of the ladino clover before nitrogen was applied, and additional nitrogen merely resulted in the elimination of what little clover was left. Brome grass in the pastured plots gave good results, and additional nitrogen, though it increased yields appreciably, had no deleterious effect on the stand of clover.

Time-of-Planting Trials with Smooth Brome Grass. (W. G. Colby.) Successive summer seedings of smooth brome grass (Canadian strain) and ladino clover, both with and without a light seeding of oats, wheat, or rye, showed that early seedings were much better than late ones. Seedings made on August 19, 1942, resulted in an excellent stand of both brome grass and clover by the summer of 1943. Seedings made on September 2 resulted in a fair stand of brome grass but no ladino clover. Later seedings resulted in very poor stands of brome grass. A light seeding of oats had an injurious effect on the August seeding but was of some benefit to later seedings. Late seedings with wheat or rye showed some benefit from the companion crop.

These results indicate that summer seedings of smooth brome grass should be made early — probably not later than is safe for the summer seeding of alfalfa or ladino clover — and without a companion crop of oats, wheat, or rye.

Winter Hardiness of Orchard Grass Strains. (W. G. Colby.) The winter of 1943-44 was a severe one from the standpoint of winter injury to vegetation. Observations on winterkilling in a three-year-old nursery of orchard grass strains showed the following results:

1. Strains showing no apparent injury: Commercial, Scandia II, Tammisto.
2. Strains showing some injury: Brage, Tardus II, O. A. C. No. 1.
3. Strains showing severe injury: S26, S37, S143, Akaroa, New Zealand.

Potato Seed Treatments. (C. V. Kightlinger and H. M. Yegian.) Experimental work was done in 1943 to ascertain the comparative tolerance of potato varieties to different disinfecting seed treatments and the effectiveness of these treatments in controlling rhizoctoniose and scab.

Several different seed treatments were used on Green Mountain, Irish Cobbler, Chippewa, Katahdin, Earlaine, and Sebago potatoes which were slightly to moderately infected with rhizoctoniose and slightly infected with scab. At the time they were treated, the potatoes were either completely dormant or just starting to sprout. The treatments used were mercuric chloride, mercuric chloride plus acid, yellow oxide of mercury, Semesan Bel, Sanoseed, Spergon, and Fermate, all of which were used carefully according to the directions.

The inorganic mercury treatments injured the tubers of Chippewa, Katahdin, Earlaine, and Sebago varieties, but not the tubers of Green Mountain and Irish Cobbler varieties. The organic treatments caused no noticeable injury to the tubers of any of the varieties. None of the treatments had any significant effect on the stands of potatoes or the vigor of the plants, and no increase in yields was obtained from the use of any of the organic treatments. Careful examination of the growing plants and later examination of mature tubers at harvest time showed little or no difference in the amount of rhizoctoniose and scab on the tubers grown from treated and untreated seed.

Potato Variety Trials. (Ralph W. Donaldson, Walter S. Eisenmenger, and Karol J. Kucinski.) Based on yields of marketable size, the ranking of potato varieties grown in plots at the Experiment Station during the season of 1943 were Warba, Chippewa, Irish Cobbler, Sequoia, Sebago, Green Mountain, Katahdin, Earlaine, Houma, S-46592, Mohawk, Russet Rural, and Pontiac.

The ranking of the five common varieties of potatoes grown in plots, based on 10-year average (1934–1943), was Green Mountain, Russet Rural, Chippewa, Katahdin, and Irish Cobbler.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

A Study of the Mineral Elements of Cow's Milk. (J. G. Archibald and C. H. Parsons.) The work with zinc has been completed and the results published in the April, 1944, number of the Journal of Dairy Science. Zinc oxide (10 grams per cow daily) was fed as a supplement to the ration of eight cows for a period of three months by the double reversal method. This consistently raised the level of zinc in the milk, the average being 5.1 mgm. per liter of milk as contrasted with an average of 3.9 mgm. when the cows were on a control ration.

The same precedure was followed during the past winter in the study of the element cobalt, which was fed as cobaltous acetate at the rate of one-half gram daily per cow. Results are not yet available, as the analytical work is still in progress.

Investigation of the Merits of Legume and Grass Silage for Massachusetts Agriculture. (J. G. Archibald and C. H. Parsons.) Practical aspects of this work during the past year have involved a trial of the following as possible preservatives:

1. Urea (10 pounds per ton of green crop).
2. Urea and molasses (urea 10 pounds, molasses 75 pounds, per ton of green crop).

3. Ground wheat (at three different rates: 100, 150, and 200 pounds per ton of green crop).

The urea when used alone proved unsatisfactory. The odor of the silage was very objectionable and an undesirable type of fermentation had taken place as indicated by the high pH (5.6), excessive amounts of butyric acid and volatile bases, and complete absence of lactic acid. The one point in favor of the urea was that apparently it preserved the carotene very well. The word "apparently" is used advisedly, for although this result confirms work done elsewhere there is some question in our minds as to its validity. It is feared that the urea, or perhaps more correctly the type of fermentation induced by the high pH developed when urea was added, may have altered certain non-carotene pigments sufficiently to permit their estimation as carotene.

When a combination of urea and molasses was used a somewhat better product resulted. The pH was considerably lower, the volatile bases and butyric acid were much lower, and considerable lactic acid was formed.

The principal idea in using the urea was to increase the nitrogen content, and hence the potential protein level, of the silage. The molasses was added not only to act as a preservative but to furnish readily available energy for those types of microflora which might synthesize the urea into protein, or at least into intermediate nitrogenous compounds. That the idea did not work well in practice is evidenced not only by the unsatisfactory quality of the silage as already noted, but also by rather definite evidence that much of the urea was lost by leaching. The average nigrogen content of the leachings from the experimental silo for four years previously was 0.30 percent; when the urea was used it was nearly double that amount (0.56 percent).

Excellent silage resulted when 150 pounds or more of ground wheat was used. The pH was satisfactory (4.3), volatile bases were low, butyric acid was either low or absent, and there was a relatively high content of lactic acid. The silage had a mild, pleasing odor and was very palatable to the cows. The herdsman observed that it was the best quality silage he had fed in the eight years of experience with grass silage.

The biochemical studies mentioned last year have been continued. The outstanding conclusion from this phase of the work is that the kind of crop and the stage of maturity at which it is harvested are of more importance in determining the quality of silage than the preservative used. Preservatives are of some benefit under certain conditions; but wherever it is practicable to control moisture content by wilting the crop before storage, an excellent grade of silage can be made without the use of a preservative. The one disadvantage of wilting (or of letting the crop become more mature before cutting, which is another way of reducing moisture) is that the carotene losses are somewhat higher than where preservatives have been used.

The Effect of Feeding Synthetic Thyroprotein to Milking Cows. (J. G. Archibald.) This project, initiated in April, 1944, is being conducted in cooperation with Cerophyll Laboratories Inc. of Kansas City, and in collaboration with the State Department of Mental Health. Eighteen milking cows in the Holstein herd at the Medfield State Hospital are being used for the work. The objective is to ascertain the effects of feeding this synthetic hormone to milking cows for relatively long periods of time. It is already known that the feeding of it causes a definite positive response in milk secretion; the question which at once arises and which it is the aim of this project to help answer is: Is this positive stimulus lasting and how does it affect the cows in those respects other than milk production?

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Nitrification in Soils Containing Plant Residues of Varying Lignin Content. (James E. Fuller, cooperating with the Agronomy Department.) This study was conducted on a sandy loam soil, characteristic of the Connecticut Valley tobacco lands in Massachusetts. The field was divided into six plots, and each plot into a sufficient number of strips to permit the planting of the several cover crops, which included tobacco, corn, artichoke, buckwheat, barley, rape, sudan, sorghum, oats, rye, wheat, millet, and sunflower. The plots were plowed as follows: two plots early, after the cover crops were well up; two in mid-season, after the crops were well developed but not hardened; and two at the end of the season, after the plant materials had matured and hardened.

The following season tobacco was planted over the whole field. Soil samples representing all of the strips on all six plots were collected early, before the tobacco was planted; in mid-season: and late, after the tobacco had been harvested.

Two series of laboratory studies were made of the nitrifying capacity of the soil: one in which dried blood (1 gm. per 100 gm. soil) was mixed with the soil, and a second in which ammonium sulfate (50 mgm. N per 100 gm. soil) was employed. Equal quantities of these mixtures were put into glass tumblers and water was added and maintained at optimum moisture content. The tumblers were allowed to stand at room temperature for four weeks, and then nitrate determinations were made (phenol-di-sulfonic acid method, A.O.A.C.).

The results of the analyses failed to indicate any relationship between the nitrifying capacity of the soil and the cover crops plowed under. Attempts to correlate the nitrification figures with the tobacco crop yields and indices also failed to show any demonstrable relationship. The only deduction that could be made was a general one: that matured and hardened plant residues plowed under late in the season apparently exerted a depressing effect on the nitrifying capacity of the soil as compared with the effects of the residues plowed under early and in mid-season.

Bacteriological Studies of Rural Water Supplies. (James E. Fuller.) In the routine bacteriological testing of rural water supplies in this laboratory, the coliform bacteria encountered are frequently classified as intermediates of the group: that is, they do not give the differential reactions of either the fecal type *Escherichia coli* or of *Aerobacter aerogenes* which is commonly encountered in soil. As a result, the interpretation of tests is often difficult. In the present study a number of these cultures have been tested by routine standard tests (lactose fermentation, Endo's agar, and "Imvic" reactions) over a temperature range extending from 37° to 46° C. (Eijkman test for *E. coli*). Results indicate that a majority of contaminated rural water supplies have received their contamination from surface wash rather than from sewage.

Relation of Chloramine-Resistant Bacteria to Milk Supplies. (James E. Fuller.) Preliminary work on this project has consisted of isolating and describing bacteria that have resisted chloramine (chlorine-ammonia) treatment as it is applied to the Amherst water supply. A number of false presumptive tests have been encountered in the water since the chloramine treatment was started. Results indicate that these false tests are caused by coliform bacteria that have been inactivated by long absence from their natural environment, combined with non-coliform bacteria. The relationship of these bacteria to milk supplies will be the next phase of the study.

Bacteriological Study of Septic Tank Efficiency. (James E. Fuller.) This project was intended to be a cooperative study with the Division of Engineering of the Massachusetts State Department of Health, with whom it originated. The purpose of the study was, and still is, to study the effect of different sewage retention periods on the bacterial and chemical quality of the effluent from septic tanks. A tank was constructed having three compartments. Sewage from one of the college dormatories was fed from a common receiving chamber into these compartments through orifices of such size as to provide three different retention periods for the sewage.

State Department of Health representatives designed and supervised construction of the installation, and its operation was originally the responsibility of Western Massachusetts District Engineering Office in Amherst. The design of the tank proved to be faulty, and the state engineer in charge entered the Army. The project then was taken over by the Experiment Station and assigned to the Bacteriology Department. Attempts to operate the tank satisfactorily proved futile, and the Army Air Corps cadets were removed from the college dormitory which supplied the sewage. As a result, the project was suspended until the dormitory is once more occupied to provide sewage. Meanwhile, plans are underway to redesign and reconstruct the tank in the effort to improve its operation. The future of the project depends on the effectiveness of the reconstruction, which is being supervised by the Engineering Department of the College, and upon the dormitory being occupied to provide an adequate supply of sewage.

Recovery of Agar from Used Laboratory Media. (James E. Fuller and John M. Woodward.) The purpose of this study was to develop a rapid and efficient method for recovery of agar that would be practical for small laboratory use. The method developed follows:

Preparation. Melt the used media and filter through a layer of cheesecloth. Put into beakers to solidify, in a refrigerator if haste is necessary, or otherwise at room temperature. Cut the solid agar into small bits and then force it through a wire screen ¼ or 3/8 inch mesh. Put into a cheesecloth bag for washing.

Washing. (1) If running water can be used, the time required for washing the agar may be substantially reduced. Suspend the cheesecloth bag in a container deep enough to permit complete immersion of the agar. Run water gently and continuously through the container for about 6 hours. By that time the agar will be clarified, and the Fehling's and biuret tests will be negative. (2) If it is not practicable to use running water, the bag of agar may be suspended in 3 liters of water for each liter of agar. Start the washing in the morning and change the water in the evening, the next morning, and the next evening. A half day of washing the third day should complete the process satisfactorily. Either method of washing should recover about 90 percent of the theoretical yield of agar.

Drying. After the agar has been washed, suspend the bag to permit drainage of surplus water, then spread the agar in a thin layer in a shallow pan and dry at 45° C. The dried agar may be used in the same way as commercial agar.

The recovery of agar from media containing dyes is not recommended because the bleaching process is tedious and is apt to impair the gelling property of the agar.

The Effect of Physical and Chemical Agents on Plate Counts. (James E. Fuller and Thomas Sparkes.) One of the limitations of bacteriological plating technique is the difficulty of breaking up clumps of bacteria. In this study both market milk and sterile milk artificially inoculated were employed. Rates of shaking were 200, 400, and 900 per minute, with and without broken glass. Two and five minute periods were employed with each rate. Counts were not substantially increased over those obtained by the "Standard Methods" procedure. Several commercial wetting agents were employed, as well as Ivory soap. None gave sufficiently improved results to justify their use in routine plating.

Vitamin and Amino-acid Requirements of Non-pyogenic Streptococci. (James E. Fuller and Ruthe Galler.) Certain of the non-pyogenic streptococci from the mouth or intestines are considered of importance as indicators of pollution. All of these types may be found in swimming pool water, and those from the mouth have been suggested as logical indicators of unsatisfactory cleaning of eating and drinking utensils. There are no simple direct methods of identifying these organisms and this study was made in the effort to develop some such method.

Representative non-pyogenic streptococci were cultivated in a synthetic medium. Vitamins (riboflavin, pantothenic acid, and pyridoxine) and amino acids (tryptophane, tyrosine, lysine, argenine, methionine, valine, and glutamic acid) were incorporated in the medium in various combinations. Each organism required all of the amino acids and all of the vitamins employed. It was not possible to substitute para-aminobenzoic acid for any of the vitamins mentioned.

Laboratory Service, December 1, 1942, to June 30, 1944. (James E. Fuller.)

Milk, bacteria counts	297
Ice cream, bacteria counts	115
Water, bacteriological tests	191
Total	603

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osman.)

The Dutch Elm Disease Problem. Ceratostomella ulmi (Schwarz) Buisman, the causal fungus of the Dutch elm disease, has been isolated from 17 trees in eight municipalities in Massachusetts, and to date (June 1944) affected trees have been removed and burned as follows:

	1941	1942	1943	1944
Alford	1			
Egremont		3	2	2
Great Barrington		1	1	1
Mount Washington				1
Pittsfield				1
Sheffield		1		1
Westfield		1		
West Stockbridge			1	

Breakage of trees caused by ice storms in December 1942 and January 1943 contributed to the increase in elm material suitable as breeding places for the principal carrier of the disease, a bark beetle (*Scolytus multistriatus* Marsh.). The beetle is now known to be present generally in Massachusetts east of Worcester County and has been reported widely in Berkshire County and Hampden County in addition to six towns in Hampshire County.

In an attempt to reduce the quantity of elm items which might contribute to the spread of this disease, municipal tree departments cooperated in a program for treatment or disposition of the elm material involved. Timely selective treatment is a most important consideration in the control of the disease, and the Massachusetts Tree Wardens' and Foresters' Association, together with Local Moth Superintendents, have planned regional meetings throughout Massachusetts for the summer to formulate further plans for Dutch elm disease control throughout the State.

At the present time, surveys and recommendations for control practices are made by the Experiment Station in regions where the disease occurs, and sanitation practices are performed by the Massachusetts Department of Agriculture and the municipalities and property owners concerned. Elm material found to be infested or suitable for infestation by carrier beetles should be utilized as fuel or debarked by June 1 in any year, as a means of checking the increase in the population of the vectors of the disease. Tree wardens, foresters, arborists, fire wardens, highway departments, state departments, and public utilities have materially aided in this practical method of protecting disease-free elms, and other means of treatment are being explored constantly in cooperation with the Department of Entomology.

Other Tree Problems. Fifty-six diseases of thirty-two species of trees including eight diseases of elm were identified from approximately 320 specimens and inquiries received during the year. The *Cephalosporium* wilt of elm was reported from one additional municipality in which the disease has been found in Massachusetts. *Verticillium* sp. was isolated from several species of woody plants, and one specimen was collected in a municipality from which the writers had no previous report of the fungus.

Soon after the leaves developed in 1943, wilting of foliage occurred on maple trees in all parts of the State. In some cases trees died, especially Norway maples, while individual branches commonly were affected also on sugar maple. Several factors were involved, but the only fungus isolated which is known to be a primary cause of disease was *Verticillium* sp. Field studies will be continued during 1944 in locations where affected trees were reported.

Rust of red, green, and possibly other species of ash trees, caused by *Puccinia peridermiospora* (Ell. & Tr.) Arth., was particularly prevalent in the coastal regions of Massachusetts during early summer. Because of the large number of inquiries received concerning this disease, a circular was prepared to facilitate the handling of requests.

An unusually large number of shade and ornamental trees, particularly evergreens, died or failed to produce satisfactory foliage in 1944. Contributing factors were presumably the drouth of the previous summer, deep freezing of the ground in a relatively dry condition in the absence of snow cover in winter, bright sunlight of winter, and drying winds. Previous to the appearance of widespread injury, recommendations for maintaining street trees in a safe condition and for pruning diseased parts of trees, treatment of tree wounds, sanitation practices, and the use of disease-resistant trees were prepared for municipal tree departments. More recently, a report on tree damage in association with winter conditions has been prepared.

Foliage of trees throughout the State, in common with many food plants, suffered from the effects of the heavy frost on May 19 and 20, 1944. In some cases all leaves on trees were destroyed, while all degrees of leaf injury from slight to relatively extensive were also noted. Among the more common trees, sycamores, oaks, beeches, sumacs, walnuts, butternuts, hickories, maples, alders, and elms, in order of listing, were injured more or less significantly; but doubtless many other woody plants with soft growth were also affected.

A number of inquiries concerning wood-destroying fungi have been received during the past year. Probably this is a result of the nonavailability of wood and wood products for replacement purposes. In most cases the use of treated wood could have prevented fungus damage, but treated woods as well as materials for treatment, are not always obtainable.

Municipalities were greatly handicapped in carrying out tree disease control programs because of the shortage of manpower. A program providing for the treatment of trees by part-time workers was suggested to help meet the emergency and has proved workable. In an effort to get cooperation on the part of the public in municipal tree protection programs, public utilities arranged for the distribution of cards announcing Massachusetts Agricultural Experiment Station Bulletin 397 entitled "A Civilian Program for Tree Protection." Details of the operation of the program were included in a report. The response by the public was extremely gratifying, and municipalities and utilities have requested that further study be given to the matter of recommending methods for educating the public in street tree problems.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modification of Environment. (W. L. Doran.) In cooperation with John S. Bailey of the Department of Pomology, especial attention has been given to the propagation of high-bush blueberry and beach plum by softwood cuttings, and papers have been published on those subjects. [1,2] Cuttings of blueberry rooted best if taken 2 to 3 weeks before the first fruits ripened, treated with indolebutyric acid or indolepropionic acid, and set in sand–sphagnum peat. The method is a timesaver as compared with the former use of hardwood cuttings. Beach plum cuttings, treated with indolebutyric acid, gave best results if taken when fruits were about one-eighth inch in diameter; and by no method previously described has the beach plum been so rapidly and readily propagated. Early July cuttings of Myrobalan plum rooted well after treatment with naphthaleneacetic acid

Manetti stock, for grafting roses, is not now available in sufficient quantities and at the request of a large grower of greenhouse roses work on their propagation by cuttings was begun. Two-bud cuttings of rose rooted well in sand–sedge peat after treatment with mixtures of a Hormodin and the fungicides Arasan or Spergon. These fungicides added to indolebutyric acid in talc caused no injury to cuttings of the several species with which they were used. In work with Lawrence Southwick of the Department of Pomology, such use of Spergon prolonged the life of unrooted cuttings of apple. Cuttings of hemlock rooted better if taken from the north side of a tree, better and more rapidly if treated with indolebutyric acid solution followed by powder dip treatment with indolebutyric acid in talc plus Spergon.

Rooted white pine cuttings grew about 5 inches, erect and symmetrical, in their second year.

Cuttings of most of the woody plants used rooted better in sand–sedge peat than in sand–sphagnum peat.

Late fall cuttings of Franklinia, Tripterygium and Marsdenia rooted well without treatment; but the rooting of similar cuttings of *Orixa japonica*, *Colutea media*, *Indigofera amblyantha* and a mulberry was improved by treatment with root-inducing substances.

---

[1] Doran, W. L. and Bailey, J. S. Propagation of high-bush blueberry by softwood cuttings. Mass. Agr. Expt. Sta. Bul. 410. 1943.

[2] Doran, W. L. and Bailey, J. S. A second note on the propagation of beach plum by softwood cuttings. Amer. Nurseryman 78:8:7–8. 1943. (Mass. Sta. Contrib. 496.)

Study of Diseases of Plants Caused by Soil-Infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) Especial attention has been paid this year to investigations of the use of urea, dichromates, sodium nitrate, formaldehyde, and other materials as soil fungicides for the control of damping-off and for the control of onion smut; also to the control of damping-off of vegetable seedlings other than by the use of soil fungicides and to certain seed treatments for use with vegetables.

The application of a very dilute solution of formaldehyde to soil immediately after seeding is a safe, convenient, and simple method for the prevention of post-emergence damping-off. At the request of the Du Pont Company, an article was written on the subject and published in their Agricultural News Letter.[1] Such treatment with formaldehyde is readily combined with subirrigation immediately after seeding, and L. H. Jones and the writer published on that method.[2]

In the absence of any chemical soil treatment against damping-off fungi, stands of vegetable seedlings under glass may be improved by postponing the first watering. Stands of eight commonly grown vegetables were better when soil was not watered until three to five days after seeding.

In work with Thomas Sproston, Jr., on onion smut, soil treatments with sodium nitrite, Fermate, or urea markedly reduced the severity of the disease; but urea, unless applied to soil long before seeding, may interfere with germination or growth.

Urea proved to be a safe and effective soil fungicide with peas when used on a limed sandy soil (0.2 milli-equivalents of exchangeable H per 100 gm. soil), but it gave poor results in soils which were unlimed or not sandy.

Fermate, applied to soil immediately before seeding, or Elgetol, ammonium dichromate, or potassium chromate, applied to soil immediately after seeding, gave good and safe control of damping-off of certain vegetables.

As seed treatments for vegetables, ammonium, potassium, or sodium dichromate, diluted with graphite, gave good results, comparable to those obtained with new proprietaries.

Seed treatments of beet with Arasan, of cucumber with Semesan, and of lettuce with Spergon prevented pre-emergence damping-off equally well whether soil was first watered 1, 2, 3, 4, or 5 days after seeding and whether the temperature of the water applied was 40° or 100°F.

Soaking seeds of eight commonly grown vegetables in water for various lengths of time immediately before seeding did not sufficiently hasten germination or emergence to affect either pre- or post-emergence damping-off.

Effect of Soil Temperature on Leaf Pattern of Tobacco Mosaic Virus. (L. H. Jones.) Seedlings of Havana Seed tobacco were established at a soil temperature of 70° F. One fourth of the plants were inoculated with a mosaic virus, and 24 hours later the soil temperatures were altered to establish a range from 50° to 95° at 5-degree intervals. The inoculated plants at all temperatures showed the typical pattern of mosaic infection by the 13th day; but on the plants at 90° and 95°, terminal growth gradually stopped and a rosette of frenched leaves appeared at the top, while at temperatures below 90° the common mosaic pattern continued. These results were confirmed when the pots at 95° were interchanged with those at 50° soil temperature.

---

[1] Doran, W. L. Soil treated with formaldehyde after seeding to control damping-off. Agr. News Letter of E. I. du Pont de Nemours and Co. 11:3:47-49. 1943.

[2] Jones, L. H. and Doran, W. L. A practical method for sterilization and subirrigation of soil in flats. Flor. Exchange 100:22:9, 11. 1943. (Mass. Sta. Contrib. 482.)

This preliminary work indicates that frenching of tobacco leaves inoculated with a mosaic virus may be induced by a high soil temperature; or else there was associated with the mosaic virus a frenching virus, the effects of which are apparent only at soil temperatures of 90° and above.

Soil temperature had a marked effect on the development of uninoculated tobacco plants. Growth was slow at temperatures below 65°, and increasingly rapid at the higher temperatures. The uninoculated plants showed no evidence of frenching at any of the temperatures.

Effect of Soil Temperature on Certain Forage Grasses. (L. H. Jones.) Seedlings of brome grass (*Bromus inermis* Leyss.), meadow fescue (*Festuca elatior* L.), perennial rye grass (*Lolium perenne* L.), and timothy (*Phleum pratense* L.) were established at a soil temperature of 65° F., which after 18 days was altered to produce a range of temperatures from 50° to 90° at 10-degree intervals. Fescue, rye, and timothy, according to values of growth and dry matter produced, had an optimum soil temperature of 70°; brome grass did best at 90° and poorest at 50°; rye and timothy did well at 50° and poorly at 90°; and fescue did well through the whole range of temperatures employed.

Creosote Injury to Plants. (L. H. Jones.) Wherever creosote fumes are evolved in confined spaces, such as cold frames, there is certain to be serious injury to plants. Creosoted lumber covered with soil has not been harmful to seed germination or the growing plant in any of the experiments. However, when the creosoted wood was above the soil line and consequently above leaves, as in a seeded flat, injury occurred, appearing first as a rolling of the leaves, usually upward and inward. Continuous exposure to the fumes eventually killed the plants. Air temperature and sunlight intensity are probably contributing factors, not only in causing an evolution of creosote fumes, but also in making the plants more susceptible to injury from the fumes.

Creosoted paper used flat on the soil as a collar for the protection of cabbages against maggots did not produce injury unless there was poor air drainage or failure to remove frost protectors in the presence of sunlight. If the stems are soft when the maggot protectors are applied, it is possible that the plants can be harmed by creosote coming in contact with such tender tissue.

If creosote fumes are evolved in a sunlighted chamber, types of injury similar to those obtained with illuminating gas result. With tomato plants epinasty, early senility, and abscission were frequent results of exposure to fumes of creosote for a limited time. Longer exposures caused immediate leaf death more often to leaves of medium age than to the oldest or youngest leaves.

Weathering of treated wood may reduce the intensity of the injury, but cabbage plants showed considerable injury from wood known to have been creosoted six years previously.

Causes and Control of Decay of Squash in Storage. (E. F. Guba, Waltham.) In previous work with gourds, less shrinkage from decay after harvest occurred when the plants were protected with a fungicide during their growing period in the field. This year the effort was applied to Blue Hubbard squash. The control plots gave as good yields of mature squash and as low a percentage of immature infected squash as did the plots dusted or sprayed with fungicides.

Decay found among the small immature squashes was essentially due to *Choanephora cucurbitarum* (Bark & Rav.) Thax. brown rot, and *Macrosporium cucumerinum* E. & E. black spot rot. Some bacterial wilt rot, due to *Erwinia tracheiphila* was evident among the mature squash at harvest.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) With the objective of developing a tomato of desirable commercial type, immune to leaf mold and yielding fruit weighing 3½ to 5 ounces each, the Bay State tomato has been hybridized with various types which are immune to leaf mold. In the F_2 generation, segregations appeared for various degrees of susceptibility and for immunity. The population of totally immune plants varied from 72 to 86 percent; and two of the crosses produced tomatoes which averaged 2½ to 3½ and 2 1/3 to 2 3/4 ounces each, indicating that the objective may soon be realized.

Disease Resistance and Heredity of Carnations. (E. F. Guba cooperating with H. E. White, Waltham.) Project has been suspended for the duration of the war, projects on food production being considered more important.

Interrelation of Wettable Sulfur, Lead Arsenate and Lime in Apple Spraying. (Departments of Botany, Chemistry, Entomology and Pomology cooperating.) This project is intended to add to our knowledge of insect and disease control and spray injury. On this basis special consideration was given to tenacity of sulfur, particle size of sulfur, scab and plum curculio control and russet injury. As in the past, detailed reports of the work at Amherst and Waltham are compiled and submitted to the departments involved.

Miscellaneous Studies. (E. F. Guba and E. V. Seeler, Jr., Waltham.)

Control of Cabbage Club Root with Chlorpicrin. A plot of ground badly contaminated with cabbage club root fungus was treated with chlorpicrin, 25 pounds to 1000 square feet, two weeks before it was planted to clean cabbage plants from steam-sterilized soil. Growth of the plants was generally poor—in the untreated plot because of club root, and in the treated plot because of club root and chlorpicrin gas persisting in the soil long after application. Although root infection was less in the treated plot, more and better heads developed where the soil had not been treated. This is in line with results of previous tests of various chemicals which have been advocated for controlling club root. Our results over the years show nothing significant in favor of chemicals applied to the field in advance of planting; and we are led to accept the use of new or uncontaminated land as the only practical method of controlling the club root disease under our conditions.

Cooperative Vegetable Seed Treatment Demonstration. These demonstrations were sponsored by the American Phytopathological Society in cooperation with the states to study the efficacy of various newer chemical seed treatments, and to standardize the pre-treatment of seeds for the control of seed decay and damping-off. The results of the trials in the different states will be summarized and published in the Plant Disease Reporter, U. S. Department of Agriculture. The best chemical treatments for each vegetable type considered at Waltham, representing the mean of five replicates, are as follows:

Bean (Lima)	Spergon, .20 percent by weight
Bean (Snap)	Fermate, .20 percent by weight
Beet	Yellow Cuprous Oxide, 2.0 percent by weight
Carrot	U. S. R. n. 604, 1.5 percent by weight
Corn (Sweet)	Arasan, .18 percent by weight
Spinach	Fermate, .25 percent by weight
Onion	Fermate (excess dosage)
Pea	Spergon, .168 percent; Thiosan, .168 and .335 percent

Studies on the Identity and Control of a Stilbaceous Mold in Gas Purifying Sponge. Our attention was invited to a compact moldy growth in sponge layers of iron oxide and wood shavings in the gas purifying boxes at the Everett Plant of the Boston Consolidated Gas Company. The sealing of the sponge impeded the flow of gas and interfered with its purification. The fungus was determined by Dr. David Linder, Harvard University, as *Sporocybe Borzinii* Goidanich, which is the imperfect stage of *Petriella Lindforsii* Curzi. What is known of the fungus would indicate that it is indigenous to wood. A few samples of wood shavings from stock piles were examined in a search for the Sporocybe fungus but none of it was found. Information has been obtained on the temperature and pH relations of the fungus and upon the lethal action of heat and formaldehyde, which will be compiled for publication.

DEPARTMENT OF CHEMISTRY

Walter S. Ritchie in Charge

Chemical Investigation of the Onion. (Emmett Bennett.) An analysis of the tops and bulbs of the Ebenezer onion has been made on samples representing various stages of growth and on those cultured in distilled water in sunshine–darkness and in darkness. In general, the trends of some of the constituents of the Ebenezer onion indicate that the cultural period may be divided into two parts. The first part, consisting of about two-thirds of the total growing period, is spent in developing a top of great synthesizing powers. The second is characterized by a rapid gain in weight by the entire plant, followed by a more or less complete removal of solutes to the bulb. This period is initiated by a softening of the neck which occurs because new leaves are not being formed. As a result of these physiological processes it may be said in general that in the tops the content of total ash and of all the nitrogen fractions, determined quantitatively, decreased with maturity accompanied by an increase of soluble sugars until signs of maturity develop; in the bulbs the content of all constituents increased.

The chief points of interest in these trends are:

1. That the amides accumulate in the bulbs, especially during the second period.
2. That the total nitrogen of the bulb at maturity is soluble to the extent of about 80 percent.
3. That reduction of nitrates appears to take place in the bulb.

In comparison with the normal, the chief changes which occurred in the onions in artificial cultures were:

1. That transportation of solutes from the tops to the bulbs occurred very slowly during 139 hours in complete darkness.
2. That complete darkness caused a more extensive utilization of the soluble carbohydrates than did sunshine–darkness.

A compound believed to be pyruvic acid has been isolated and characterized. So far as we are aware pyruvic acid has never been isolated from any of the higher plants. The crystals of the 2, 4-dinitrophenylhydrazone were greenish yellow diamond-shaped plates. The poles of the longer axis were pointed, while those of the shorter axis were curved or rounded. The compound melted at 241°C. and contained 20.20 percent nitrogen.

Phosphorus Compounds in Certain Vegetables. (Emmett Bennett.) A fractionation was made of the phosphorus compounds of 11 different vegetables into inorganic, organic, resistant esters, phytin, phospholipid and phosphoprotein phosphorus. The results indicate that the bulk of the phosphorus is in the inorganic form; that the organic fraction may be composed of widely varying amounts of resistant esters, and phosphoproteins and phospholipids; and that phytin was absent in all cases. Therefore, there are no unavailable forms of phosphorus in these vegetables.

The Chemical Investigations of Hemicelluloses. (Emmett Bennett.) The numerical values of the soluble sugars, pectic compounds, and hemicelluloses are usually not given as such but are included in the nitrogen-free extract value. Data obtained from 14 common vegetables indicate that the percentage content of soluble sugars may range from 4 to 51 percent of the dry matter or about 12 to 66 percent of the nitrogen-free extract. Pectic materials and hemicelluloses collectively may constitute from 5 to 19 percent of the dry matter or from 11 to 52 percent of the nitrogen-free extract. These data indicate that the amount of soluble sugars, pectic compounds, and hemicelluloses varies with the species, and that the numerical value of the nitrogen-free extract gives little information regarding the relative amounts of these fractions.

Hemicelluloses from corn cobs and rye straw have been isolated and purified for work designed to indicate the chemical nature of these substances.

Factors Affecting the Riboflavin Content of Milk. (Arthur D. Holmes.) Although it is generally accepted that milk is one of the rich natural sources of riboflavin, and many investigators have reported studies on the subject, there are still many phases about which knowledge is incomplete or lacking. These studies were made for the purpose of filling some of these gaps. The milk used was produced by the college herd of Ayrshire, Guernsey, Holstein, Jersey, and Shorthorn cows. The large number involved would eliminate any influence of individual characteristics of the cows. Since farm herds in this locality are made up of more than one breed of cows, and since the management and feeding of the cows were similar to those of modern, local dairy farms, the results should be applicable to commercially produced milk, in this region at least.

The Effect of Pasteurization on Riboflavin Content. (Arthur D. Holmes.) Winter milk (December and January) was assayed before and after pasteurization. The raw milk contained an average of 1.46 mg. of riboflavin per liter; after pasteurization, the milk contained 1.43 mg. per liter. Accordingly, the consumer can be assured that, from a practical dietetic standpoint, he will obtain essentially as much riboflavin from milk recently pasteurized (under the conditions of this study) as he would obtain from the same milk just before pasteurization.

The Uniformity of the Riboflavin Content of Milk Produced under Standardized Conditions. (Arthur D. Holmes and Julia O. Holmes.) The riboflavin content of milk, as reported in the literature, is extremely variable, with extremes of 0.53 and 7.8 mg. per liter. At intervals during the four months, December to March, inclusive, 80 samples of milk were taken and assayed for riboflavin. The average amount of riboflavin per liter of milk was 1.45 mg. for December, 1.50 mg. for January, 1.49 mg. for February, and 1.46 mg. for March. These results seem to justify the conclusion that it is possible to standardize the feeding and management conditions for a dairy herd sufficiently so that milk of relatively uniform riboflavin content may be produced for considerable periods of time. This would be true particularly for dairy herds that are stall fed continuously year after year. Such a source of milk would be especially helpful to the physician who desired for his patients milk with a dependable, uniform riboflavin content.

The Ratio of Ascorbic Acid, Riboflavin, and Thiamine in Raw and Pasteurized Milk. (Arthur D. Holmes, Carleton P. Jones, Anne W. Wertz, and John W. Kuzmeski.) While a considerable body of data is available concerning the ascorbic acid, riboflavin, and thiamine content of milk, not a single report was found of the assay of a milk for all three of these vitamins. Accordingly, 32 samples of milk produced by the college herd were assayed before and after pasteurization. The average values obtained were ascorbic acid 19.7 mg., riboflavin 1.51 mg., and thiamine 0.33 mg. per liter of raw milk; ascorbic acid 15.9 mg., riboflavin 1.48 mg., and thiamine 0.30 mg. per liter of the same milk after pasteurization.

The ratios of riboflavin, ascorbic acid, and thiamine were computed for both the raw and the pasteurized milk. The raw milk contained 4.6 times as much riboflavin as thiamine 13.1 times as much ascorbic acid as riboflavin, and 59.8 times as much ascorbic acid as thiamine; the pasteurized milk 4.9 times as much riboflavin as thiamine, 11.0 times as much ascorbic acid as riboflavin, and 53.8 times as much ascorbic acid as thiamine.

Ascorbic Acid, Riboflavin, and Thiamine Content of Milk as Influenced by the Ration. (Arthur D. Holmes, Carleton P. Jones, and Anne Wertz.) It is generally agreed that, under normal conditions, changing the cow's ration does not cause any significant changes in the protein, fat, and mineral composition of the milk. There is, however, a lack of agreement regarding the effect of changing a cow's ration upon the vitamin content of her milk. Since it is generally believed that young, rapidly growing grass is particularly rich in vitamins, this study was made during the interval while the cows were being transferred from the winter ration to green grass pasture ration.

When the cows were changed from the winter ration to an early pasture of rapidly growing grass, the volume of milk produced increased; the ascorbic acid content of the milk decreased from 20.3 mg. to 19.1 mg. per liter; the riboflavin decreased from 1.43 mg. to 1.26 mg. per liter; but there was no change in the thiamine content.

Effect of High-Temperature, Short-Time Pasteurization on the Ascorbic Acid, Riboflavin, and Thiamine Content of Milk. (Arthur D. Holmes, Harry G. Lindquist, Carleton P. Jones, and Anne W. Wertz.) Twenty lots of milk produced by the college herd were pasteurized, with an Electropure pasteurizer, for 22 seconds at temperatures ranging from 161° to 181°F. Samples of the milk taken just before and immediately following pasteurization were assayed for ascorbic acid, riboflavin, and thiamine. The average values obtained were 16.4 mg. per liter of ascorbic acid for the raw and 16.6 mg. for the pasteurized milk; 1.50 mg. of riboflavin for the raw and 1.50 mg. per liter for the pasteurized milk; and .36 mg. of thiamine for the raw and .35 mg. per liter for the pasteurized milk. Hence, considered from a practical standpoint, milk pasteurized by this type of high-temperature, short-time procedure has as satisfactory ascorbic acid, riboflavin, and thiamine content as before pasteurization. In contrast, there were significant vitamin losses when milk was pasteurized at 145°F. for thirty minutes.

Ascorbic Acid, Riboflavin, and Thiamine Content of Chocolate Milk. (Arthur D. Holmes, Carleton P. Jones, Anne W. Wertz, and W. S. Mueller.) The term chocolate milk is very misleading since this product is very frequently made with cocoa. In this study both the American-process and the Dutch-process (alkali) cocoa were used.

Sixteen samples of chocolate milk were prepared by mixing 30 cc. of cocoa syrup and 240 cc. of freshly pasteurized milk. The pasteurized milk contained

16.6 mg. of ascorbic acid, 1.56 mg. of riboflavin, and .33 mg. of thiamine per liter. The American-process chocolate milk contained 15.4 mg. of ascorbic acid, 1.50 mg. of riboflavin, and .31 mg. of thiamine per liter; and the Dutch-process chocolate milk contained 11.5 mg. of ascorbic acid, 1.37 mg. of riboflavin, and .25 mg. of thiamine per liter. From a practical standpoint, these results indicate that chocolate milk made with American-process cocoa had essentially the same vitamin value as the pasteurized milk but the chocolate milk made with Dutch-process cocoa contained much less ascorbic acid, riboflavin, and thiamine. Since these results were obtained from assays made as soon as the chocolate milk was compounded they may not apply to chocolate milk that has been stored for varying periods of time before being consumed.

The Ascorbic Acid Content of Late-Winter Tomatoes. (Arthur D. Holmes, Carleton P. Jones, and Walter S. Ritchie.) The tomato is frequently listed as one of the richest vegetable sources of ascorbic acid (vitamin C), field-grown, fully ripened, vine-matured, summer tomatoes containing about 25 mg. of ascorbic acid per 100 grams. However, during the late winter and early spring months one finds on the market tomatoes that in neither color, taste, nor physical appearance compare in quality with the summer tomatoes. This study was concerned with the value of these late-winter tomatoes as a source of ascorbic acid.

The tomatoes were purchased from local stores in retail plackages or by the pound, just as a homemaker would purchase them for home use. The results of 58 assays showed that average late-winter tomatoes contain 8.8 mg. of ascorbic acid per 100 grams. In computing the vitamin C value of a diet containing late-winter tomatoes, therefore, one should not assign to them more than one-third the ascorbic acid value ordinarily used for fully ripe, summer tomatoes.

Riboflavin Content of Immature Massachusetts Lettuce. (Arthur D. Holmes.) The lettuce used in this study was produced by the Agronomy Department under growing conditions quite typical for this locality.

The immature Boston head lettuce was picked during a three-weeks' period just before it began to form heads. At this stage all the leaves were spread out and exposed to light and sunshine. The plants were pulled from the ground early in the morning. The entire leafy portion of the plant except the lower midribs was used and the assays were started within twenty minutes after the plant was taken from the ground, a condition quite different from that for lettuce purchased in the store. The riboflavin content of the 17 samples varied from 0.105 mg. to 0.155 mg. with an average of 0.124 mg. per 100 gm. These results show that immature Boston head lettuce eaten shortly after it is picked is a good vegetable source of riboflavin, and the evidence accumulated indicates that farmers and victory gardeners might well begin to consume lettuce before it reaches the heading stage.

CONTROL SERVICES

Philip H. Smith in Charge

The fertilizer, feed, seed and dairy laws are administered as one service and the operations of each of these, with the exception of the dairy law, are completely reported in annual bulletins issued for that purpose.

Besides the regular control activities the laboratory, through its staff, cooperates liberally on numerous research projects active in other departments and also performs many analytical and testing services for State institutions and for private citizens who, because of the nature of their problems, deserve this consideration.

Under the dairy law 8,834 pieces of Babcock glassware were tested and 102 Certificates of Proficiency were issued during the one and one-half years ending June 30, 1944.

The enlarged emphasis on the vitamin values of all feeds, and commercial feeds in particular, and the increased interest in the mineral content of poultry mashes and in the protein quality of meat and fish products used for feed demands continual expansion of the analytical service in those fields.

Restrictions in the use of certain materials and the scarcity or entire absence of others have made complete compliance with the feed and fertilizer laws difficult. The trade on the whole are to be commended for the attempt they are making.

War gardens have augmented the demands made upon the Seed Laboratory for checking of vegetable seeds. This additional work has been handled without an increase in staff partly due to the fact that the laboratory has been able to secure new supplies and equipment which not only facilitate the work but also bring methods and procedure more nearly up to date.

Two members of the Control Staff are on military leave. The positions have been temporarily filled.

THE CRANBERRY STATION

East Wareham, Massachusetts

H. J. Franklin in Charge

Weather Studies. (H. J. Franklin, H. F. Bergman, and N. E. Stevens.) The various relations of the weather to cranberry culture were given very extensive attention during the year. Most of these studies have been followed over a long term of years and some of them were finished and the results published in Bulletin 402. Studies of the relations of the weather to cranberry yields are being continued.

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Hill Fireworm (*Tlascala finitella* (Walker)). The infestation of this pest on the Burrage bog, mentioned in previous reports,[1] continued to be extensive in 1943. The bog was completely flooded on June 4 for 36 hours to stop the egg-laying of the moths and again on June 13 for 36 hours to kill the worms that had hatched. In spite of these treatments, the worms became very abundant among the vines. Apparently many of the moths had escaped the first flooding by flying ashore and then returned to lay more eggs on the bog.

Eggs of this insect, laid in confinement on June 4, hatched on June 9, only 5 to 6 days after they were laid. When first laid, the eggs were oblong-oval and yellow or reddish yellow, the largest of them being very nearly a millimeter long. They became bright crimson within a day and a half and remained so up to within half a day of their hatching.

The newly hatched worms had blackish heads and reddish bodies.

As in the two previous years, the worms did most of their work well down among the vines in a zone 3 to 6 inches above the bog sand.

Cranberry Spittle Insect (*Clastoptera*). The nymphs were first found in their spittle on June 7. Flooding for 24 hours as soon as occasional flowers have opened proved to be a very effective treatment on a number of bogs.

---

[1] Mass. Agr. Expt. Sta. Bul. 388:37, 1942; and 398:26, 1943.

Spotted Fireworm (*Cacoecia parallela* (Rob.)). The bog in Marion mentioned in last year's report[2] was seriously attacked by this insect again this year, the last of May. The worms were completely killed out by flooding for 30 hours on June 5 and 6. The winter water had been removed from this bog on May 10.

Cranberry Scale (*A. oxycoccus* Woglum). A rather severe infestation of this species on a part of the large bog of the Nantucket Cranberry Company was treated very successfully in the early spring, after the removal of the winter flood, with the following sprays, each used at the rate of about 500 gallons an acre[3]: (1) Dry lime-sulfur, 16 pounds in 100 gallons of water; (2) Pratts Spra Cream, 1 gallon in 100 gallons of water.

Nearly all the scales were killed by these sprays. The lime-sulfur did almost no harm to either the cranberry vines or their crop. The oil spray stunted the berries somewhat and retarded the new vine growth rather noticeably.

Grape Anomala (*Anomala lucicola* Fab.). Grubs of this species were sent to the Japanese and Asiatic beetle laboratory at Moorestown, New Jersey, to have their susceptibility to the milky disease organism determined. Mr. C. H. Hadley, in charge of the laboratory, reported the following results.

> Further reference is made to earlier correspondence, particularly Dr. Hawley's letter to you of January 18, regarding the susceptibility of *Anomala lucicola* to type A milky disease. Our tests to determine the susceptibility of this species to infection by type A milky disease have now been completed, and you will be interested in the results.
>
> The grubs used in the test were those which you kindly sent us late in November 1942. Of the surviving larvae of that shipment, 10 were inoculated by direct injection with spores of the type A milky disease, *Bacillus popilliae*. Five of these larvae developed typical type A vegetative forms and spores. After 10 days incubation at 86°F. the infected larvae differed but little in macroscopic appearance from the noninfected specimens which had been injected, the typical chalky-white appearance, characteristic of milky diseased Japanese beetle larvae, not being evident.
>
> Twenty of the healthy larvae were exposed to infection in soil in which the concentration of type A milky disease spores was 2 billion spores per kilogram of soil. These larvae were incubated at a temperature of 86°F., examined at frequent intervals, and held until all the larvae had pupated or died. After 25 days incubation, each was examined microscopically for the presence of milky disease. In no case was there evidence of positive infection.
>
> These tests would seem to indicate that this species possesses a relatively high degree of natural immunity to type A milky disease. Of course the number of larvae employed in the test was rather limited, so that probably it should not be said that this species is completely immune to field infection from type A disease. However, in view of the fact that direct injection of spores known to be viable produced only 50 percent infection under incubation conditions known to be very nearly optimum for the development of the disease, it may be assumed that this species is certainly less susceptible to the disease than Japanese beetle larvae, and is probably rather highly immune under ordinary field conditions.
>
> Specimens of the infected larvae which did react positively were forwarded to the Division of Insect Identification of the Bureau and identified by Dr. Boving as *Anomala lucicola*. His identification confirms that given by you in your letter of January 18, 1943.
>
> Incidentally, Dr. Hawley's letter to you of January 8 is now known to be incorrect in so far as the susceptibility of the larvae to feeding in infected soil is concerned. At that time several of the larvae in the feeding test were suspected of being infected with milky disease. Later, however, when blood smears of the suspected larvae were examined microscopically it was found that these larvae were not infected with milky disease.

---

[2] Mass. Agr. Expt. Sta. Bul. 398:26, 1943.

[3] Information from Marland Rounseville, the foreman.

Prevalence of Cranberry Insects in 1943.

1. Bumblebees and honeybees rather abundant nearly everywhere on Massachusetts bogs during the cranberry flowering; somewhat less abundant than in 1942.
2. Cranberry fruit worm (*Mineola*) much more prevalent than for quite a number of years.
3. Infestation by gypsy moth (*Porthetria*) rather light in Plymouth County but somewhat greater on most of the outer Cape than in 1942.
4. Black-headed fireworm normally abundant, about as in 1942.
5. Firebeetle (*Cryptocephalus*), almost none.
6. Spotted fireworm (*Cacoecia*) rather prevalent, but less so than in 1942.
7. False armyworm (*Xylena*) normally abundant, less prevalent than in 1942.
8. Cranberry girdler (*Crambus*) more abundant than for many years.
9. Cranberry weevil (*Anthonomus*) normal in abundance.
10. Cranberry spittle insect and tipworm fully as troublesome as usual.
11. Spanworm infestations generally light.

Control of Cranberry Bog Weeds. (Chester E. Cross.) About 50 experiments in chemical weed control gave the following results:

1. Kerosene is decidedly more toxic to rushes when sprayed in April and early May than at any time later in the growing season. At 400 gallons per acre, kerosene killed *Juncus bufonius*, *J. canadensis*, *J. acuminatus*, *J. effusus*, and *J. pelocarpus*. No injury to cranberry flower buds resulted from kerosene spraying till treatments were made on May 28.
2. Gasoline sprayed on bogs at 200 and 400 gallons per acre caused no injury to vines in treatments made before May 15. Horsetail, loosestrife, and various grasses and rushes were killed by the sprays.
3. Various concentrations of lime-sulfur solution were sprayed on bog weeds late in April. Neither weeds nor cranberry vines were injured by them.
4. Ammonium sulfamate sprays were as toxic to cranberry vines in April and May as they are later after the development of new growth. Ivy sprayed with these solutions before sending out its leaves in the spring showed no injury.
5. Established clumps of *Juncus canadensis* were completely killed on new bog by pouring into each 25 cc. of a copper sulfate solution of 1 pound in 20 gallons of water. The adjacent hill cranberry vines were not injured.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Nutritive Value of Milk—Plain versus Chocolate Flavored. (W. S. Mueller.) The toxicity of cocoa powder was found to be correlated with its tannic substances content. Therefore, if cocoa could be analyzed accurately for tannic substances, then dieticians could select a cocoa powder which is low in these substances and thus avoid most of its toxic effects.

None of the various methods for the determination of tannic substances in cocoa powder which were investigated proved entirely satisfactory. Commercial cocoa powder contained on an average 11 percent of tannic substances, as determined by the Ulrich method, which is the one most commonly used today. Ulrich's method was modified and improved. By this improved method, commercial cocoa powder contained an average of only 9.5 percent of tannic substances.

Overrun of chocolate milk is an important consideration in formulating laws or regulations pertaining to the product, and in determining plant losses, cost of the product, and nutritive value. Commercial chocolate milk was found to vary in overrun from 4 to 14 percent. The average overrun was higher in chocolate milk prepared with syrup than in chocolate milk prepared with dry ingredients because the syrup often contains a considerable amount of water. A formula has been developed for computing the overrun in certain kinds of chocolate milk, and it is expected that further study will make it applicable to all chocolate milks.

Indications are that the destruction by cocoa of certain vitamins in milk may be significant. This should be of interest to the many nutritionists who have endorsed the inclusion of cocoa in milk as a means of adding more widespread appeal to this protective food.

A Study of the Effect of Certain Antioxidants on the Flavor and Keeping Properties of Milk and Some of Its Products. (W. S. Mueller.) Further attempts were made to find a chemical method which would detect and measure oxidative rancidity in butter and other dairy products. The method desired is one that will (1) detect the very earliest stages in the process of rancidification, (2) measure quantitatively the state of oxidation, and (3) make possible a comparison of the potential keeping qualities of various dairy products.

The "chlorophyll value" test, which has been recommended for testing vegetable oils, has been investigated and appears to have a doubtful value as a test for butter fat rancidity or stability. This test appeared to measure the degree of rancidity which had been activated by light, but not that activated by heat. The chief difficulty encountered when this test was applied to butter fat was the masking of the "endpoint" in the titration by the yellow fluorescence of butter fat. The use of various light filters did not remedy the difficulty.

Sterilizing Agents for Dairy Use. (W. S. Mueller, E. Bennett, and J. E. Fuller.) In an attempt to find a sterilizer for dairy equipment which would take the place of chlorine, 45 samples of wetting or cationic agents have been collected, and 15 of these samples have been compared with a commercial chlorine sterilizing compound. Of the 15 samples already studied, 8 showed sufficient sterilizing properties to warrant further study, while 7 were discarded as ineffective.

Potassium meta bisulfite was found to be unsuitable as a sterilizing agent for dairy equipment because it was too corrosive to metals and also because its sterilizing properties were too weak. This was found to be true for acid sodium sulfite also. Sulfur dioxide was found to be a strong sterilizing agent but very corrosive. Buffering all three of the sulfur compounds in order to reduce their corrosiveness also greatly reduced their sterilizing properties.

The fact that sulfur compounds are excellent fungicides has led many people to believe that they are also good germicides. The negative results obtained in this study should aid in clearing up the misconception.

Effect of High-Temperature Short-Time Pasteurization on the Ascorbic Acid, Riboflavin, and Thiamin Content of Milk. (A. D. Holmes, H. G. Lindquist, C. P. Jones, and Anne W. Wertz.) Over a period of 18 months, samples were taken from 30 lots of raw milk, and taken again after the milk had been pasteurized by the high-temperature short-time method of pasteurization (in an Electro-Pure pasteurizer) at temperatures varying from 161° to 181°F. The vitamin assays for ascorbic acid, riboflavin, and thiamine showed that there were no significant losses of these vitamins due to this method of pasteurization.

DEPARTMENT OF ECONOMICS

Philip L. Gamble in Charge

Effects of the War and Readjustments in Massachusetts Agriculture. (David Rozman.) Recent agricultural production trends in Massachusetts have been analyzed, primarily on the basis of AAA records from farm contacts, to determine farm needs, particularly labor requirements for achieving maximum production under war-time conditions. From this analysis it appears that 59.1 percent of all farmers depend on hired labor; of these 9.7 percent use only year-round labor, 29.5 percent only seasonal labor, and 19.9 percent both regular and seasonal. On dairy farms dependency on hired labor, expressed in man work units, varies from 24 percent of total farm work in the Connecticut Valley to 49 percent in Norfolk County. For other counties the dependency of dairy farms on hired labor is as follows: Essex 42; Worcester 26; Berkshire 33; Plymouth 46; Barnstable 27; Bristol 24; and Middlesex 36 percent.

On the basis of war-time requirements for food and the necessity of concentrating on the most economical types of production, determination has been made of the maximum production capacity of Massachusetts agriculture. This has been prepared in cooperation with a college committee in connection with the national program of agricultural adjustment. In working out this program stress has been placed on obtaining a greater amount of direct food crops from Massachusetts land resources and on making more efficient use of local grasslands to relieve the pressure on imported feed for the maintenance of our increased numbers of livestock.

DEPARTMENT OF ENGINEERING

C. I. Gunness in Charge

Cranberry Storage Investigation. (C. I. Gunness, H. J. Franklin, and H. F. Bergman.) Early Black cranberries from the 1943 crop were stored in a refrigerated storage at 45 degrees and a similar lot stored in a commercial screen house provided with natural ventilation. The berries were picked and stored on September 8, 1943, and removed from storage on November 2. Those stored at 45 degrees suffered a storage loss of 7.2 percent, while those stored in the screen house showed a loss of 26.5 percent. These results are typical of results obtained in former years. The losses could have been reduced still more if the berries had been held at a lower temperature, the least loss occurring at 35 degrees.

An attempt was made to hold cranberries in a modified atmosphere containing 5 percent carbon dioxide and 2 percent oxygen, but failure to make the room air-tight upset this experiment and no results were obtained.

Poultry House Investigation. (C. I. Gunness and W. C. Sanctuary.) Observations on ventilation of poultry houses were continued during the two seasons 1942-43 and 1943-44. In the first season observations were limited to three pens which had also been observed during 1941–42. One pen was completely insulated, one partially insulated, and one non-insulated. In 1941–42 all pens were ventilated with natural draft. The litter in the non-insulated pen contained 36.6 percent moisture on March 11, that in the partially insulated pen 26.3 percent, and that in the insulated pen 25.9 percent. The observation made on March 11 is indicative of the general condition of the litter throughout the season. In 1942–43 the insulated pens were run as in the year previous but an electric fan was installed in the non-insulated pen, drawing in 60 cubic feet of air per minute for the 100 hens in the pen and recirculating about 500 cubic feet of air over the litter. The litter that year had about the same moisture content in all three pens. This arrangement produced more floor draft than was desirable, so a smaller fan was installed for 1943–44 with a circulation of only 150 cubic feet per minute over the litter. This apparently was not sufficient to keep the moisture content of the litter down to that in the other pens. Another attempt will be made during the coming season to obtain sufficient circulation to keep the litter dry without creating an objectionable floor draft. No attention was given to adjustments or changes in the ventilation of the fan-ventilated pen either season, a feature which is of considerable interest to the poultryman.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne and W. D. Whitcomb.) Work on the cooperative project was continued with attention focused on several lines of research.

Tests were made to study the effect on apples of adding DN-111 to the standard spray combination of lead arsenate and wettable sulfur in the regular applications immediately following bloom. The calyx application (May 27), made under conditions of moderate temperature and humidity and followed by similar weather conditions, caused no injury whatever. The first cover spray (June 3), however, was followed by general and quite conspicuous burn, which was most extensive on Baldwin and Greening and considerably less on Wealthy and Cortland. By mid-July the falling of the worst affected leaves and development of new growth had very nearly obliterated any evidence of injury. No appreciable cut in yield was noted.

On July 20 and August 9 sprays were also applied to peaches, pears, plums, and cherries in the college orchard and no ill effects were noted. Temperature in the period following the sprays rose to 80° or above.

Applications of DN-111 and D-4 to approximately 20 different types of deciduous ornamentals indicated that during June these materials, even at moderate temperatures, caused moderate to serious injury in most cases; while in late July and August similar applications, even at temperatures as high as 84°, caused no evidence of any damage to foliage, almost without exception.

Counts of red mite made 24 hours after application of D-4 dust showed 56 mites per 100 leaves compared with 2296 mites on leaf samples taken just before dusting, a 97 percent reduction. DN-111 at 1¼ pounds to 100 gallons in similar tests gave 95 percent reduction, and at 1 pound to 100 gallons, a 98 percent reduction. The difference in results was due to the density of foliage and difficulties in securing thorough coverage in the case of the trees given the 1¼-pound dosage.

Summer applications of dinitro materials are often coincident with the presence of honeybees working the blossoms of cover crops in the orchard. Beekeepers are very sensitive to the possibility of losses from sprays and dusts, and every new material used for insect control becomes an object of suspicion. In tests to determine the effects of dinitro compounds on bees, D-4 dusted on honeybees caused only slightly greater mortality than occurred on normal bees in the same length of time. When compared with rotenone, nicotine, or pyrethrum dusts, the toxicity of D-4 was very low. DN-111 (at a dilution of 1¼ pounds to 100 gallons) in a sugar solution proved to be more toxic, for all the bees in the test died within 5 days.

In summer applications of DN-111 at Waltham, on McIntosh and Northern Spy trees infested with 18 to 21 European red mites per leaf on July 28, a spray of DN-111, 1 pound in 100 gallons, and a spray of DN-111, 1 pound, lead arsenate 3 pounds, and wettable sulfur 4 pounds in 100 gallons, each reduced the population of mites 98 percent six days after the treatment. A natural reduction of 11 percent occurred on the unsprayed trees during this period. Thirteen days after these sprays were applied, the mite population had been reduced 97 percent. The natural reduction on unsprayed trees was 94 percent.

On Baldwin trees having an infestation of 381 white apple leafhoppers per 100 leaves on August 31, a spray of DN-111, 1 pound in 100 gallons, reduced the population 94.7 percent eight days later, while a natural decrease of 9.02 percent occurred on unsprayed trees.

Potato Spraying Experiments. (A. I. Bourne.) The experimental plots were planted May 7, and the plants in all the plots were alive and green up to the first killing frost on October 5 and 6. The potatoes were dug (by machine), picked, and bagged on October 13.

Potato flea beetles appeared as soon as the plants were above ground and persisted in great abundance until mid-August.

Leafhopper infestation was comparatively light, and no records of serious outbreaks were received.

During late June and early July there was a very considerable amount of stalk infestation by European corn borer larvae. While the number of injured stems was high, most of the damage was confined to lateral stems, so that for the most part the attack simply caused a moderate pruning and the injured growth was very soon replaced. Hundreds of second-brood moths were harbored among the plants during the day, but there was little or no evidence of late-summer injury by second-brood larvae.

Potato aphids developed a serious infestation following the very hot and dry weather of early July. Delay in applying control measures and temporary local shortages of nicotine allowed serious infestations to build up in several large commercial plantings. A thorough application of nicotine in the sprays of July 20 and 28 eliminated these insects as a source of danger in the experimental plots. These two applications were made on bright, sunshiny days with temperature ranging from 84° to 86° to facilitate the rapid evolution of nicotine.

The test plots received 10 applications at approximately weekly intervals from July 15 to September 3. Because of the war emergency and to conserve copper, the bordeaux mixture was based on a 8-8-100 formula instead of the standard 10-10-100 strength.

There was practically no disease in any of the plots. Out of more than 233 bushels of potatoes harvested, only 18 pounds were discarded because of disease.

Evaluation of the different treatments on the basis of flea beetle damage showed a definite increase in protection following the use of calcium arsenate. The addition of calcium arsenate reduced flea beetle damage by 16½ percent in the plots which received the standard 4-4-50 bordeaux; in the plots which received the 4-2-50 bordeaux the reduction was 32½ percent; and in the plots which received half strengh bordeaux the reduction was 35 1/3 percent. In all the plots in which bordeaux plus calcium arsenate was applied, the average number of leaf punctures per square inch of leaf surface was practically the same regardless of the strengh of bordeaux. There was a marked difference, however, in the amount of flea beetle feeding in the plots which received bordeaux alone. Compared with the 4-4-50 plot, the average number of feeding punctures per square inch of leaf surface in the low calcium plot was 28 percent greater; and in the ?-2-50 bordeaux plot, 35 percent greater. This would indicate that, regardless of the copper content, in any low-calcium bordeaux the addition of calcium arsenate is important for protection against flea beetle attack.

In general, increased yields were recorded in the plots where calcium arsenate was added to the bordeaux. In one small plot which received a low-copper – high-calcium bordeaux, the yield fully equalled that in the standard 4-4-50 bordeaux plot.

Castor Bean Extractives. (A. I. Bourne.) Preliminary tests of an insecticide based on extractives of the castor bean plant with ricine as basic constituent showed that the material had excellent wetting and spreading qualities, even on plants with a waxy surface such as onions. As a contact spray against certain species of aphids, the material has shown very definite promise. Several tests were made to check the tolerance of various types of garden plants and ornamentals, and in no case was any injury to foliage noted.

The material showed fairly good results against onion thrips. Apparently all that were actually hit by the spray were killed; in other words, all those which were feeding exposed on the leaves.

The material seemed to have a repellent effect, as there was very little evidence of feeding by the Mexican bean beetle after it was applied.

Control of Onion Thrips. (A. I. Bourne.) There was a comparatively light infestation of thrips in the Connecticut Valley in 1943, and most of it was well distributed over the fields of set onions. The combination of thrips migration in middle and late July and hot, dry weather in early August promoted a rapid increase in thrips population on seed onions, which was maintained at a high level until well beyond mid-August.

A dinitro dust prepared for use on growing plants reduced the number of thrips from 31 per plant to 3, a 91 percent reduction. The application was heavy and a slight trace of burn was noted. The material gave definite promise.

The standard combined spray of nicotine sulfate and soap gave 90.2 percent reduction of thrips. Derris and Ultrawet reduced thrips from 100 per plant to 14, an 87 percent reduction, and also showed a pronounced residual action. A dinitro spray (prepared for summer use) proved 92 percent effective but showed little residual effect. A new antimony compound furnished for experimental use by the Crop Protection Institute showed good killing action but possessed somewhat inferior wetting and spreading qualities on the smooth waxy leaves of onion. In spite of this handicap it gave 84 percent immediate reduction in the number of thrips and reinfestation was slow.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) For the second consecutive year, Early Jersey Wakefield cabbage showed definite resistance to injury by the cabbage maggot, 87 percent of the plants being commercially uninjured, while seven other varieties of different types suffered from 20 to 64 percent more injury. Golden Acre, with only 23 percent commercially uninjured plants, showed the greatest damage.

The first eggs were found on May 10, 1943, and the general field infestation was moderate, 77 percent of the untreated plants being commercially injured.

The most effective treatment was the application of calomel–talc dust in a mound around the stem of the plant. Perfect commercial control was obtained from dust containing either 4 percent calomel or 2 percent calomel, although the 4 percent calomel–talc dust gave 10 percent more actual protection than the 2 percent dust. Corrosive sublimate solution in two applications at weekly intervals gave good control at concentrations of 1-1280, 1-1920, and 1-2560. For each reduction of 50 percent in concentration, the effectiveness was reduced about 7 percent. Semesan at the rate of 3 ounces in 10 gallons of water gave 86 percent protection in two applications. Tar paper discs when applied carefully gave perfect commercial control on both cabbage and cauliflower, and it was demonstrated that this is the most practical treatment in the home garden.

The results of these studies have been summarized and published in Bulletin 412.

Control of Squash Vine Borer. (W. D. Whitcomb, Waltham.) The field infestation of the squash vine borer at Waltham in 1943 was moderately severe, averaging 4 borer injuries per vine in Blue Hubbard and 2 per vine in Buttercup. The Buttercup is a relatively small-stemmed variety and appeared to be less attractive to the borer, but the borer injury was more destructive to the vine than to the larger-stemmed Blue Hubbard.

Four applications at weekly intervals during July of nicotine sulfate 1-250, and nicotine sulfate 1-500, plus Volck 1 percent, gave good control and reduced borer injury 72 and 80 percent. The addition of bordeaux mixture 2-2-50 to these sprays failed to cause significant differences either in borer control or yield.

The addition of 33 percent cryolite to a nicotine-copper dust increased the control 25 percent and gave satisfactory protection.

The Value of Control Measures to Supplement the Standard Spray Program for Apple Pests in Massachusetts. (A. I. Bourne, in cooperation with the Departments of Pomology and Plant Pathology.) All of the early-season sprays were applied within a temperature range of 57° to 67° and with low to moderate humidity. In the subsequent cover sprays the temperature range was 66° to 80° and humidity moderate. No evidence of spray injury was noted throughout the entire season.

The season proved to be very favorable for most insects and especially so for scab. Foliage infection was evident very generally in all blocks, although the fruit was fairly well protected. Unsprayed checks showed 96 percent scabby fruit.

Examination of the fruit at harvest showed 23 percent codling moth and 17 percent curculio damage and 5 percent scab on the plot which received the standard schedule. Unsprayed trees showed 72 percent codling moth, 66 percent curculio, and 96 percent scab.

A special application of fixed nicotine between the 2d and 3d cover sprays reduced codling moth damage to 13 percent, a reduction of nearly 44 percent from that in the standard schedule.

The nicotine in DX base, in a modified schedule with reduced strengths of lead arsenate, held codling moth damage to 5 percent, a 78 percent reduction from the standard schedule, with approximately the same protection against scab.

One application of a fixed nicotine spray replacing lead arsenate in the 4th cover spray reduced codling moth injury to 7 percent; and when an additional application of fixed nicotine followed in mid-August, injury was cut to 5 percent, a reduction of 78 percent from the standard schedule and 92 percent from the unsprayed checks.

Insecticides for the Control of European Corn Borer. (A. I. Bourne.) Throughout practically all the Northeastern States, European corn borer developed one of the heaviest infestations and caused the greatest amount of damage in recent years. Relaxation of fall clean-up programs did much to aggravate the situation. Damage was not confined to corn. Potatoes were heavily infested by first-brood larvae and early varieties were severely damaged. Many varieties of flowers were attacked, and some commercial plantings of dahlias were ruined.

In the middle Connecticut Valley moths were emerging by May 24, and the larvae began to appear by June 10. In the experimental plots insecticides were applied on June 11, 16, 21, 25, and 30. Precipitation was comparatively light during this period and caused no serious interference with any application.

Preharvest examination of the experimental plots for early evidence of attack showed that 85 percent of the plants sprayed with derris, 89 percent of the plants dusted with fixed nicotine, 55 percent of the plants given fixed nicotine sprays, but only 15 percent of the unsprayed plants were free from infestation. Subsequent counts of borer population showed an average of 5½ borers per plant in the check plots, 2½ in the fixed nicotine sprayed plots, 2 in dusted plots, and 1½ in the plots sprayed with derris.

In the dusted plots 95 percent of the corn harvested was free from borers, and 94 percent of the total yield was of marketable grade. In the plots sprayed with derris, 91 percent of the ears were clean and 89 percent of marketable grade. A schedule of fixed nicotine spray at 3 pounds to 100 gallons dosage gave 90 percent of the yield free from injury and 86 percent of marketable grade. A 2-pound dosage allowed 89 percent borer free ears, with 85 percent of the total yield of marketable grade. In the unsprayed check plots, while 64 percent of the crop harvested was borer free, only 55 percent of the total yield was fit for market.

In late pickings the contrast between treated and check plots was greater. Only 35 percent of the last picking in the check plots was of marketable grade.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) The fruit buds of peaches were practically all destroyed by the unusually low temperatures of the winter (1942-43) in Massachusetts, and some injury to the wood also resulted. There was practically no peach crop in this State or throughout most of the northern peach-growing area. Only two growers requested *Macrocentrus* parasites of the oriental fruit moth and these orders were filled by purchase from the Connecticut Agricultural Experiment Station through the cooperation of Doctors Friend and Garman. A few colonies for experimental release were supplied by Dr. H. W. Allen of the U. S. Bureau of Entomology and Plant Quarantine Laboratory, Moorestown, N. J.

Apple Maggot Emergence. (W. D. Whitcomb.) In 1943 the number of apple maggot flies was generally below normal but many of the flies remained active and laid eggs over a long period, which resulted in moderate infestation in many commercial orchards and heavy infestation in home orchards.

The emergence of flies in the cages at Waltham was the lowest since the cages have been in operation, being only 9 percent of the possible total and 18 percent of the expected total.

Emergence of Apple Maggot Flies, 1943, *Waltham, Mass.*

	Cultivated Soil	Sod
First Fly Emerged	June 25	July 6
25 Percent of Flies Emerged	July 9	July 6
50 " " " "	July 14	July 10
75 " " " "	July 26	July 15
Last Fly Emerged	August 6	August 5

Control of Common Red Spider Mite on Greenhouse Plants. (W. D. Whitcomb, Wm. Garland, and Wm. E. Tomlinson, Jr., Waltham.) Life history studies of the common red spider mite at constant temperatures were continued on various host plants particularly beans, lettuce, and cucumber. Significant differences in the life cycle on different host plants were found but they were not so consistently correlated with the pH of the plant sap as in previous studies, indicating that other factors may be involved. About twice as many eggs were laid on beans as on the other host plants in this series.

Spraying experiments on greenhouse roses showed that 4 applications of 40 percent nicotine sulfate 1-400 with or without soap did not control the common red spider mite satisfactorily, but permitted the spider population to remain at about 40 per leaf throughout the experiment. A commercial thiocyanate spray which has been recommended as a substitute for rotenone sprays during the war emergency gave good control of the pest on roses but caused severe injury to foliage even when diluted 1-1200.

In further experiments with a commercial mixture containing 20 percent di-cyclohexylamine di-dinitrocyclohexylphenate, good control on roses was obtained with 3 applications of spray containing ½ ounce and 1 ounce of the toxicant in 100 gallons of water, and excellent control with 1 to 3 applications of spray containing 2, 3, or 4 ounces in 100 gallons. About 4 ounces of the toxicant in 100 gallons of water was the critical dosage, and nearly perfect control was obtained whether this amount was applied in several applications at a smaller dosage or in one application at the critical dosage. On carnations the mortality was about 30 percent greater than on roses when less than a critical dosage was used but about equal when a dosage of 4 ounces per 100 gallons, or more, was applied.

No foliage injury from the DN spray occurred on roses or carnations in these experiments. Foliage injury resulted on chrysanthemums and in another series on roses, when this material was combined with a neutral copper (26 percent metallic) fungicide 1-50; and growers have reported injury from this combination during high temperature in mid-summer.

Napthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and Wm. Garland, Waltham.) Experimental fumigations with a mono-dichlornaphthalene-napthalene mixture previously reported were continued, and a series of studies at controlled temperatures and relative humidity was completed.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) In 1943 the curculio infestation was the greatest in the history of the Waltham Field Station orchard and 90 to 100 percent of the fruit on unsprayed trees was damaged.

The gallonage experiments in which ¾, 1, or 1¼ gallons of spray was applied to each 100 square feet of area of the tree were continued. With the extremely heavy infestation, the ¾-gallon dosage was inadequate. The 1-gallon dosage was the best. The 1¼-gallon dosage was inconsistent, being the least effective on Wealthy and Spy and the most effective on McIntosh.

Cryolite at the rate of 4 pounds in 100 gallons was 12 to 17 percent less effective than lead arsenate at the same rate and russeted the fruit of Delicious badly. DN-111 at the rate of 1 pound in 100 gallons failed to control the curculio and caused a definite bleaching of the leaf veins following successive applications to tender foliage at the pink and calyx periods.

New Fruit Insect Pest. (W. D. Whitcomb.) A general outbreak of the spotted tentiform leaf miner (*Lithocolletis blanchardella* Fabr.) occurred throughout Worcester and Middlesex Counties in 1943, with particularly severe infestations in orchards at Marlboro and Groton. Although this insect has been present in

Massachusetts for several years, it has never been so destructive as it was in some orchards this year. Many of the infested trees lost one-third or more of their leaves and the remainder were badly mined.

Reports indicate that this leaf miner is not likely to be an annual pest but may be abundant for 2 or 3 years after which it is held in check by parasites. Satisfactory control should be obtained by spraying with nicotine sulfate when the moths are flying and laying eggs. There are usually three generations annually; but if the first generation is controlled by spraying at about the pink bud stage, further infestations will be prevented.

Biology and Control of the Grape Plume Moth and Grape Cane Girdler. (W. D. Whitcomb and Wm. E. Tomlinson, Jr., Waltham.) Studies of the Grape Plume Moth were completed and the results were published as Bulletin 409.

Insectary studies of the grape cane girdler were conducted on potted grape vines. The first eggs were laid by caged beetles on June 2 and oviposition continued until July 14. The greatest number of eggs was laid June 3 and 4, and 77 percent were laid from June 3 to 21. The average number of eggs laid was 10.5 per female, but two beetles laid 16 eggs each. The average length of life from oviposition to adult was 47.5 days of which 20 were spent as a boring grub in the grape cane. Limited observations on caged beetles indicate that they hibernate under stones and long grass rather than under fallen grape leaves beneath the vines.

Spraying the vines with cryolite 3 pounds and Fermate 1 pound gave better protection than applications of lead arsenate and bordeaux mixture or wettable derris powder.

Biology and Control of the Celery Plant Bug. (W. D. Whitcomb, Waltham.) The celery plant bug (*Lygus campestris* L.) continued to be destructive to celery in the Boston market garden area in 1943, and some fields suffered losses as high as 50 percent of the early crop and from 10 to 25 percent of the late crop. The loss on the early crop was correlated with hot weather during the early part of the growing season which caused heart rot and seed stalk development that was easily confused with plant bug damage. Severe heart rot and dwarfing of the plant was definitely connected with plant-bug injury in cages where celery confined with 2 bugs per plant was severely injured; while celery from which plant bugs were excluded, and where the heart stalks were punctured by a needle to imitate plant-bug injury, grew normally.

The bugs spend the winter as adults, and in 1943 they first appeared in the celery plantings about May 15. There are two generations during the summer. The number of first generation bugs per 100 plants was greatest from June 26 to 29 soon after the majority of the nymphs had hatched. During hot weather the period from hatching to adult is about 35 days, and 98 percent of the bugs had become adult on July 10. At Waltham the white celery varieties such as Supreme Golden and Early Fortune were most heavily infested, having 173 to 199 bugs per 100 plants at the peak of infestation.

The first infestation on late celery was observed about July 13, about 2 weeks after the plants were set out, and nymphs were found on July 20. Two peaks of infestation of the second-generation bugs developed on the celery, first on August 17 and again on September 11 to 14.

Insectary studies in late August and September showed the average period from egg to adult to be 45 days. This period varied from 39 to 43 days while the mean daily temperature was 66° to 67°F., and from 48 to 50 days when the mean temperature was 61° to 62°. Incubation of the egg required 9 to 13 days, averaging 11.16 days. There are five nymphal stages, the first four requiring 4 to 6 days and the last averaging 12.8 days.

In the late planting the white and yellow varieties of celery were more heavily infested than the green varieties, averaging 73 more bugs per 100 plants in the semi-weekly counts. The most heavily infested variety was Fullheart, with 3749 bugs per 100 plants during the season and 320 per 100 plants at the maximum infestation on September 11. The most resistant variety appeared to be Morse's Utah, a coarse green variety which does not bleach well. It had only 538 bugs per 100 plants throughout the season, and 44 per 100 plants at the height of the infestation. The standard variety, Summer Pascal, had a low infestation throughout the season.

Spraying and dusting experiments against the first brood of bugs on early celery showed satisfactory protection from nicotine dusts and sprays, and from nicotine pyrethrum dust in three applications. The nicotine–pyrethrum dust reduced the number of bugs 97 percent, and only 4 live bugs per 100 plants were found in counts made one day after treatment. Black Leaf 155–bordeaux mixture spray, and Black Leaf 155–lime dust also gave good protection. On the untreated plants the infestation increased 81.3 percent during the period.

On the second planting, the nicotine–pyrethrum dust again gave the best protection. When applied at weekly intervals between July 19 and September 20, only 95 bugs per 100 plants were found during the season, compared to 350 bugs per 100 plants on the untreated check. Counts on the day following application showed a 95 percent reduction in the number of bugs from this dust. The addition of 2 pounds of soap flakes dissolved in each 100 gallons increased the effectiveness of nicotine sulfate spray 1-800 by 28 percent, and of a commercial pyrethrum spray 1-400 by 17 percent. The least effective treatment was nicotine sulfate 1-800 without soap, in weekly applications.

Applications with a spray gun which drove the spray into the heart of the celery were 5 to 10 percent more effective than applications with a mist nozzle.

Applications at intervals of 2 and 3 weeks reduced the number of bugs found 24 hours after treatment as much as weekly applications, but permitted greater reinfestation in proportion to the interval between treatments.

Investigations on the Effect of Insecticides on Honeybees. (A. I. Bourne and F. R. Shaw.) In feeding tests to determine the relative toxicity of arsenicals and fluosilicates to bees, fluorine compounds at the rates recommended for control of shade tree pests seemed to be fully as toxic as arsenicals. In a comparison of the effects of dusts on bees, rotenone and pyrethrum dusts were most toxic, nicotine was third, sulfur fourth, and DN dust fifth in order of toxicity. Since DN dust would be applied during the summer when bees are active, the fact that it did not cause appreciable death is significant.

Tests of materials suggested as bee repellents included creosote at various dilutions, carbolic acid, and a proprietary phenol compound known as Milkol. All creosote applications produced blossom injury. The heavier concentrations produced some leaf injury, which soon disappeared, however, because of the dropping of the affected leaves. Materials applied shortly after full bloom did not materially affect the set.

Experiments to determine the effect of the materials suggested as repellents on the length of life of bees were conducted by feeding the "repellent" material in sugar syrup. The length of life of bees fed these materials was compared with that of check lots receiving sugar syrup. In all instances the addition of the "repellent" shortened life. Whether this was due to insecticidal action or to starvation was not determined.

Sprays to Prevent Scolytid Infestation of Individual Elm Logs. (W. B. Becker.) *Orthodichlorobenzene and Fuel Oil.* At Amherst, unseasoned elm logs were thoroughly sprayed when dry with orthodichlorobenzene and No. 2 fuel oil mixed one to eight by volume and applied at the rate of 240 c.c. per square foot of bark. This was done on May 14, five days before *Hylurgopinus rufipes* (Eich.) beetles started to dig their first egg galleries in the vicinity. A small hand-operated compressed air sprayer was used. The crevices where the beetles commonly enter the bark were well saturated, and each log was turned over during the application so all sides could be reached. The sprayed logs together with unsprayed control logs were then exposed to beetle infestation in the shade. *H. rufipes* was the only scolytid which attacked the logs. Compared with unsprayed control logs of similar size, 99.5 percent prevention of *H. rufipes* infestation per square foot of bark was obtained, based on the number of brood galleries which became established in the logs. Based on the number of progeny which emerged from the bark during the season (beetle exit holes), 100 percent prevention was obtained; and based on the combined number of progeny which emerged and which were still present in November, 98.5 percent prevention was obtained by spraying.

Creosote and Kerosene (*strained*). Unseasoned elm logs were thoroughly sprayed with creosote and kerosene mixed one to four by volume and applied at the rate of 160 c.c. per square foot. This was done on May 20, one day after *H. rufipes* beetles started to dig their first egg galleries in the vicinity. Complete prevention of all *H. rufipes* infestation was obtained for the entire season. When this spray was applied to parts of other logs which were also subsequently piled in the shade, the unsprayed portions were infested with *H. rufipes*.

These results suggest that, under these conditions, thoroughly coating the entire bark surface with either of these two spray mixtures just before the beetles lay eggs in the spring may be expected to prevent *H. rufipes* infestation to a great extent for the entire season. If the entire bark surface is not thoroughly covered with a sufficient amount of spray material, the scolytids may infest the unsprayed portions. Since the beetles commonly dig into the bark at crevices, the spray must penetrate into all such places.

The large elm borer, *Saperda tridentata* Oliv., was also apparently repelled by both of these spray mixtures, but was abundant in the unsprayed logs.

While neither of these spray mixtures is pleasant to work with, the creosote-containing spray is much more disagreeable to handle. When the creosote is mixed with kerosene, a black precipitate is produced which must be removed before the liquid is poured into the spray tank. The fire hazard must also be taken into consideration with sprays of the type used in these experiments. However, these materials may prove useful in preventing infestation of logs thrown on town dumps and other locations where the fire hazard and injury to adjoining vegetation may not be a problem.

Sprays to Kill Scolytids Breeding in Individual Elm Logs. (W. B. Becker.) *Orthodichlorobenzene and Fuel Oil.* At Westfield,[1] scolytid-infested elm logs were thoroughly sprayed during July 1942 with the orthodichlorobenzene–fuel oil mixture described in the previous section, at the rate of 52.5 c.c. per square foot of bark. Both *H. rufipes* and *S. multistriatus* brood galleries with only immature progeny were in the logs at the time of spraying. None had emerged. After the spray application the sprayed logs, together with unsprayed control logs, were piled in partial shade. Compared with unsprayed logs of similar size, 79 percent mortality occurred in the sprayed logs, based on the number of surviving progeny (immature and emerged) of both species per brood gallery the next spring. Many *Saperda tridentata* Oliv. and some *Magdalis* sp. survived the spray application.

---

[1] Mr. W. E. Marshman, the Westfield tree warden, kindly provided the logs for this experiment and a place where the work could be carried on.

While 79 percent mortality is a considerable reduction, it would still allow more beetles to survive than is desirable in the case of a vector of a disease.

Creosote and Kerosene. Attempts to kill scolytids in elm logs by spraying the entire bark surface with 12.2 c.c. per square foot of the creosote–kerosene mixture dscribed in the previous section were not at all successful. A heavier application might be more successful.

The Prevention of Hylurgopinus rufipes (Eich.) Attack by Repeatedly Turning Unseasoned Elm Logs in the Sun during the Early Season Oviposition Period. (W. B. Becker.) Freshly cut elm logs lying in a north–south direction in the sun at Amherst were rolled 180 degrees of their circumference (1) every week and (2) every second week during the early-season oviposition period of *H. rufipes* (May 19 to July 2 in 1943). Many egg galleries were started on the lower halves, but when the logs were turned so that the sun heated the bark above the temperature which the beetles could tolerate, development in almost all cases stopped. Relatively few egg galleries reached the stage where eggs were laid in them — fewer in the logs turned every week than in those turned every second week. Of those larvae which developed from these eggs, most died when still very small. No attacks occurred after July 2, which was the last date the logs were turned. On one large log which was left in the sun unturned from May to November, the upper half was not suitable for the construction of egg galleries, while the lower half was. In comparison with control logs piled in the shade, logs turned over at one-week intervals were practically free from infestation, both on the basis of the number of beetles, per square foot of bark, which had emerged by the end of the season (November) and on the basis of the combined number of emerged progeny and immature progeny still in the bark at the end of the season. The control was practically as good where logs were turned at two-week intervals. When the logs were examined in November, none seemed to be in a condition which would be suitable for further attack the next spring.

The successful results obtained in this experiment suggest that, in certain situations, this method might prove useful in preventing an increase in the local beetle population. Of course, warm sunny weather is necessary. However, since experiments were started here in 1939, solar-produced heat has always prevented elm bark scolytids from becoming established in all or most of the upper half of elm logs exposed to the sun since spring.

Combined Use of Sprays and Solar Heat on Individual Elm Logs. (W. B. Becker.) Individual unseasoned elm logs laid in a north–south position in the sun at Amherst on July 2, 1943, were sprayed on the top half with (1) the orthodichlorobenzene–fuel oil mixture and (2) the creosote–kerosene mixture previously described and then rolled over so the sprayed half was underneath. Unfortunately, not enough *H. rufipes* beetles attacked even the control logs to furnish any comparative data. However, since attacks on entire individual logs in the shade have been prevented by spraying, and attacks on most of the upper half of untreated logs have been prevented by laying them in the sun, it seems possible that (1) laying logs to be sprayed in the sun may save much spray material since only slightly more than half of the bark area on each log need be sprayed, and (2) spraying the under half of logs in the sun may save returning at a future date to turn them over.

Spray Coverage on Elm Logs in a Pile of Cordwood. (W. B. Becker.)[1]

Good spray coverage was obtained on elm logs in a pile of logs of cordwood length by using a six-opening spray gun and a power sprayer giving 400 pounds pressure. The pile sprayed included approximately six feet of a longer pile four feet high. The spray was directed into the pile from the ends of the logs and from the top of the pile. Approximately 12 to 15 gallons of a spray (Elgetol) which left a visible deposit were applied. Immediate examination revealed that of 22 elm logs scattered throughout the pile, 12 were completely coated with spray, 9 were approximately 85 percent or more coated, whereas only one was as little as half coated. The bark surfaces not coated were areas protected from the spray stream by a branch stub or a cross stick in the pile, or where the surface of two adjoining logs lay flat against each other.

If satisfactory spray coverage can be obtained on logs inside a pile, it may facilitate the treatment of log piles to repel or kill the scolytids which are vectors of the Dutch elm disease.

Miscellaneous Biology Studies with Hylurgopinus rufipes (Eich.). (W. B. Becker.)

Beetle Emergence Throughout the Day. Although emergence of young adults from logs fluctuated from day to day and from hour to hour, seemingly being affected by the weather, by far the most of it occurred between mid-morning and late afternoon. This was shown by emergence during 1936 and 1943 from logs caged outdoors in partial shade. During 18 days in the late summer of 1936 the average emergence between the following hours (E. S. T.) was: 6–8 a.m. 1.9, 8–10 a.m. 2.8, 10–12 noon 33.9, 12–2 p.m. 69.9, 2–4 p.m. 31.4, 4–6 p.m. 8.4. During the 18 overnight periods (6 p.m. to 6 a.m.) an average of only 2.8 beetles emerged. During 15 days in the late summer of 1943 the average emergence between the following hours was: 7:30–9:30 a.m. 3.66, 9:30–11:30 a.m. 22.53, 11:30 a.m.–1:30 p.m. 63.06, 1:30–3:30 p.m. 53.06. During nine overnight periods (3:30 p.m. to 7:30 a.m.) the average emergence was only 2.78 beetles

Sex Ratio: The proportion of males to females was approximately one to one. Both sexes started to emerge from logs at the same time in mid-summer and the daily emergence of the sexes did not vary significantly throughout the season. Between July 29 and August 26, 1938, 123 males and 99 females emerged from some caged logs. Of 757 adults selected at random from specimens collected all season, 383 were males and 374 were females. In 1943, 304 males and 309 females emerged from small caged logs between August 4 and September 4.

Some New Findings of Scolytus multistriatus Marsham in Massachusetts. (W. B. Becker.) One adult beetle was found in a log which had been exposed to scolytid attack in 1942 at Amherst.

Insect Pests of Wood and of Shade, Forest, and Ornamental Trees in Massachusetts. (W. B. Becker.) During 1943 over 200 inquiries were received about these insect pests. Ants, termites, powder post beetles, aphids, and secondary tree-boring insects were received most frequently.

---

[1] Professor A. I. Bourne provided valuable assistance in planning this experiment.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Disease Resistance and Heredity of Carnations. (Harold E. White, Waltham.) Flower petal counts made on blooms from 42 varieties of carnations show that there is considerable variation in the number of petals per bloom within a variety. A few varieties were very consistent in the number of petals per flower produced. When the varieties were grouped for comparison on the basis of average number of petals, 40 percent had an average count of 25 to 50 petals; 35 percent, 50 to 60 petals; and 24 percent, 60 to 80 petals per flower. The variety Silveryln had the highest average number of petals, 97 per bloom.

Flowers with split calyces were not abundant enough for an accurate analysis of petal number as related to splitting, but material available for inspection revealed no correlation between number of petals present and degree of splitting. Extra floral parts such as ovules were found in both normal and split flowers; but, as extra ovules occurred very frequently in both types of flowers, such a condition could not be associated with the splitting character in commercial varieties.

Some 500 progeny were obtained from crosses made between disease-resistant and susceptible varieties, but data as to the hereditary nature of the disease resistance are not sufficient for analyses. The progeny segregated for two types of double flowers: 50 percent commercial doubles (normal) and 25 percent bursters (abnormal doubles); and 25 percent were singles. The data seem to indicate that splitting of calyces is of two types. One, due to specific hereditary factors, induces formation of an abnormal number of extra buds and multiplicity of floral parts within the individual blooms. Dissection of a number of the bursters produced in the seedlings showed that there were from 100 to 150 petals present and 5 to 10 immature ovules per bloom. The second type of splitting occurs in variable degrees with commercial varieties and would seem to be influenced more by environmental factors than by heredity.

Cotyledon number of seedling carnations varies from two to three and the seedling leaf character segregates in a 1 to 1 ratio. No structural characteristics were observed to be associated with difference in cotyledon number.

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Trials of eight Waltham Field Station strains of rust-resistant snapdragons with Yoder Brothers in Barberton, Ohio, showed the strains to be highly resistant to rust and valuable for outdoor culture as well as worthy of inclusion in the firm's hybridizing work with snapdragons.

Provisions were made for more extensive tests of the rust-resistant qualities of these strains by distribution of seed to eight experiment stations and one seed firm in this country. Requests for trials were received from Pretoria, South Africa, and Victoria, Australia.

The rust-resistant character of the strains has shown no indication of breaking down, and no mutant strains of the rust fungus have been observed. Selected inbred lines have been back-crossed to determine possibilities of hybrid stock for commercial flower production use. A large-flowered pink strain has been developed which shows much promise as a winter-blooming greenhouse variety.

Complete information and results on hereditary phases of the breeding work on this project have been published as Massachusetts Agricultural Experiment Station Bulletin 400, February, 1943.

DEPARTMENT OF FOOD TECHNOLOGY

F. P. Griffiths in Charge

Cranberry Research. (W. B. Esselen, Jr., H. J. Brunell, and F. P. Griffiths in cooperation with C. I. Gunness, Department of Engineering.) A drying temperature of 170°F. was found to be optimum for the dehydration of cranberries. Fresh cranberries should be either sliced or punctured prior to being dried in order to facilitate the removal of moisture. Sliced cranberries dried approximately 20 percent faster than did the punctured fruit. It was also observed that the dehydrated sliced cranberries rehydrated more rapidly than those which were punctured.

Approximately half of the ascorbic acid content of cranberries was destroyed during dehydration and practically all of it was lost when the product was stored for six months at room temperature (75°- 80°F.) in sealed containers. An attractive and tasty cranberry sauce may be prepared from dehydrated cranberries.

The Nutritive Value of Mushrooms. (W. B. Esselen, Jr., W. H. Fitzpatrick, H. J. Brunell, and A. Filios.) Commercially grown mushrooms (*Agaricus campestris*) can be dehydrated so that on reconstruction and cooking they will compare favorably in flavor and appearance with fresh mushrooms. For dehydration it is recommended that the mushrooms be thoroughly cleaned in cold water, cut into pieces, blanched in steam for 2 minutes and 15 seconds and dried at a temperature of 145°-150°F. to a moisture content of 5 percent or below. The dehydrated mushrooms should be packaged in moistureproof containers and stored at a temperature of 75° or lower.

Fresh mushrooms are a very good source of riboflavin and nicotinic acid. The thiamine, riboflavin, and nicotinic acid of mushrooms are quite stable during dehydration and storage of the dried product.

The quick freezing of mushrooms was found to yield a satisfactory and flavorful product in which thiamine, riboflavin, and nicotinic acid were well retained.

When mushrooms (*Agaricus campestris*) were fed as the sole source of protein to white rats, they survived and grew, although not to the same extent as did rats which were fed casein or soybean meal. From the results of animal feeding experiments it was concluded that all of the essential amino acids are present in mushrooms but in lower concentrations than are found in casein. Chemical analyses showed that about 63 percent of the total nitrogen of mushrooms is in the form of a protein.

By means of chemical tests the mushroom protein was found to contain the following essential amino acids: phenylalanine, histidine, leucine, lysine, arginine, tryptophane, threonine. The essential amino acids which failed to give positive tests were: valine, isoleucine, methionine. However, that these three essential amino acids were also present was borne out by the animal feeding trials.

Glass Container Research. (W. B. Esselen, Jr., J. E. W. McConnell, J. J. Powers, R. G. Tischer, N. Guggenberg, G. J. Yourga, R. Woodward, and M. A. Ewing.) In studies of the keeping quality of packaged edible oils (corn and cottonseed oils), a number of chemical and physical tests for the detection and evaluation of rancidity have been investigated. The only practical method available at present for the determination of rancidity in oils stored in sealed containers is an evaluation of the oils by organoleptic means.

Of many antioxidants tested with corn and cottonseed oils, catalase and the palmitic acid ester of ascorbic acid appear to be the most promising. Gum guaiac and nordihydroguaiaretic acid have been reported as being satisfactory antioxidants for lard; but these compounds, while possessing antioxidant powers, imparted an objectionable off-flavor to corn and cottonseed oils. In using antioxidants with edible oils it is important that the product be fresh and in good condition to start with; otherwise, much of the effectiveness of added antioxidants it is lost.

Amber glass bottles were found to be satisfactory as containers for liquid edible oils when stored under normal commercial conditions, and also convenient from the standpoint of use by the consumer.

Preliminary results indicate that riboflavin is quite stable during the canning and processing of vegetables. In such products as cut asparagus and cut green beans, there is a marked tendency for the riboflavin to leach out of the product into the brine. Thus if the brine were discarded when the can was opened, much of the riboflavin would be lost.

The carotene content of such vegetables as asparagus, green beans, corn, and peas was found to be very stable during canning and subsequent storage of the canned products in both glass and metal containers. Storage in bright sunlight for prolonged periods of time appeared to have no significant effect on the carotene content of glass-packed vegetables.

Thirteen different types of commercial and home-canning glass and metal containers were compared for their effect on the stability of the ascorbic acid in canned tomato juice. The loss of ascorbic acid during eight months' storage varied from approximately 35 to 50 percent, depending upon the type of container. In general, vacuum-sealed, commercial-type glass containers, plain tin cans, and home-canning jars sealed with two-piece metal lids were found to be superior from the standpoint of ascorbic acid retention in canned tomato juice. The differences observed in the different kinds of containers appear to be due largely to the amount of oxygen in the headspace and dissolved in the juice during processing and storage.

D-iso ascorbic acid proved satisfactory as an antioxidant for preventing the discoloration of freshly peeled peaches and pears, home-canned peaches and pears, and tomato catsup. In working with pure solutions, d-iso ascorbic acid was oxidized more rapidly than l-ascorbic acid (vitamin C). D-iso ascorbic acid was preferentially oxidized when used as an antioxidant for l-ascorbic acid and may be considered a good antioxidant for the latter substance. When these theoretical findings were applied to glass-packed tomato juice, none of the original l-ascorbic acid was lost, even under severe storage conditions, when small amounts of d-iso ascorbic acid had been added to the bottled juice. In addition to preventing a loss of l-ascorbic acid, the added d-iso ascorbic acid also prevented the juice from darkening when stored at high temperatures, and the juice maintained its original fresh flavor. For practical purposes, it would appear that, for optimum effectiveness, d-iso ascorbic acid should be added to tomato juice in amounts equivalent to 25 to 30 milligrams per pint.

Oxidation-reduction potential studies have tended to confirm the finding that d-iso ascorbic acid is an antioxidant for l-ascorbic acid, itself an antioxidant. The superior antioxidant properties of d-iso ascorbic acid over l-ascorbic acid seem to be correlated with the greater poising action of d-iso ascorbic acid, rather than with their respective redox potentials. Citrate-buffer ascorbic-acid packs were put up in plain tin cans and in commercial all-glass jars and stored at 70°F. and at 100°-110°F. The eventual ascorbic acid loss was the same in both types of containers stored at 100°-110°F., although the rate of loss was initially greater in the glass container. The potential of the tin-packed solution was lower than that of the glass-packed. In general the packs stored at 70°F. evidenced the same changes, except that slightly less ascorbic acid was lost in the tin container (the test period has not been completed yet). The redox potentials of hot-break tomato juice packaged in plain tin cans, in commercial glass jars with metal lids, and in commercial all-glass jars and stored at 70°F. are being investigated. As with the citrate-buffer ascorbic-acid packs the tomato juice packed in plain tin cans showed a lower potential, but the difference in potential between the tin container and the two glass containers was much less than with the citrate-buffer ascorbic-acid packs. Differences in ascorbic acid content were almost insignificant. Flavor changes could not be correlated with redox potential.

A survey of spoilage encountered by home canners in Massachusetts in 1942 indicated that 293 families who canned a total of 73,393 jars encountered approximately 2 percent spoilage. The amount of spoilage is not considered excessive in view of the many variables encountered in home canning at the present time. In the laboratory examination of home canned foods, bacteriological culture tests were found to be the most reliable criterion of spoilage. As represented by this investigation it would appear that about three-fourths of home-canning spoilage is due to understerilization and one-fourth to improper sealing. The boiling water bath method of processing is not adequate to destroy certain types of bacteria encountered in the home canning of low acid vegetables. While a pressure canner correctly used is satisfactory for processing, understerilization may result if it is mis-used. From experimental evidence it would appear that home-canning process times at 240°F. (10 pounds pressure) as recommended at present may be more severe than are necessary and that in many cases they might be reduced. However, before any general recommendations are made, more experimental work must be done and careful consideration given to the many variables involved.

Experimental data indicate that many of the directions provided for home canning in pressure canners do not allow for sufficient venting and in some instances might contribute to underprocessing. A venting time of at least 10 minutes is to be recommended for pressure canners of the size commonly used for home canning.

A comprehensive study has been made of different types of glass containers and jar seals available for home canning under war-time conditions, and directions for their use were made available. Although some difficulties have been reported in the use of jars and seals, it is evident that much of the trouble was caused by the improper use of satisfactory equipment. Jar rings and seals made of synthetic and reclaimed rubber have given very good results from the standpoint of making an original seal and also of maintaining it during the storage life of the canned product.

Comparison of Canning, Freezing, Dehydrating, and Salting as Methods of Home Food Preservation. (W. B. Esselen, Jr., C. Dubord, and F. P. Griffiths.) Four varieties of snap beans, two varieties of cabbage and carrots, and one variety of sweet corn at two different stages of maturity were preserved by four home methods: canning, freezing, dehydrating, and salting. The preserved products were stored for six months and changes in their ascorbic acid content, palatability, flavor, texture, and color were observed and compared. Freezing appeared to yield the most acceptable product, followed by canning and dehydration. The salted products, with the exception of sauerkraut, were unsatisfactory.

On a basis of the final cooked ready-to-serve product, the total losses of ascorbic acid (referred to the fresh product) amounted to 85-95 percent in both the canned and frozen vegetables. The dehydrated vegetables maintained their quality to a high degree during three months' storage at room temperature (75°-80°F.), but after six months a definite deterioration in flavor was observed.

Home Dehydration. (W. B. Esselen, Jr., S. G. Davis, M. A. Ewing, and F. P. Griffiths.) A method has been devised for evaluating the performance of home dehydrators and has been used as a basis for setting up minimum performance standards. For this method of food preservation an electric dehydrator with forced air circulation and thermostat is recommended. Properly designed natural draft dehydrators may be used. In general, oven drying is least satisfactory because of the difficulty in controlling oven temperatures, the temperature variation in different parts of many ovens, and the frequency with which the trays must be rotated and shifted.

The following fruits and vegetables yielded a satisfactory product when preserved by recommended methods of home dehydration: apples, cranberries, peaches, pears, blue plums, red plums, green and red cabbage, beets, green beans, spinach, kale, baked beans, green and red peppers, broccoli, white potatoes, baked potatoes, and mushrooms. Foods dehydrated at home should be dried to a moisture content of below 5 percent, packaged in moistureproof containers, and stored at as low a temperature as possible.

Dehydration of Foods in Atmospheres other than Air. (F. P. Griffiths and R. E. Morse.) The dehydration of vegetables in atmospheres of methane or natural gas, carbon dioxide, and nitrogen, versus air was investigated. Methane or natural gas dehydration was effective in preventing losses of ascorbic acid during dehydration and did not produce off-flavors in the reconstituted foods. Storage of dehydrated foods in gas atmospheres was effective in retarding ascorbic acid losses and deterioration in quality when such foods were stored at room temperature (75°–80°F.). At elevated storage temperatures (110°–120°), less protection was noted and the quality deteriorated rapidly.

Nutritive Value of Fishery Products. (F. P. Griffiths and R. E. Morse in cooperation with R. T. Parkhurst of the Poultry Department.) Work was done on the dehydration and nutritive quality of starfish meal for use in poultry feeding. Starfish can be readily ground and dehydrated. The meal contained protein of high quality and a large amount of minerals. Chicks fed up to 8 percent starfish meal grew well and utilized the protein as efficiently as control groups fed equivalent amounts of fish and crab meals.

Red Squill Research. (L. R. Parkinson and F. P. Griffiths.) Under war-time conditions it has been increasingly difficult to obtain red squill (a raticide) of high toxic potency. Work carried on during the past year indicates that it may be possible to concentrate the toxic principle of red squill in order to provide a raticide of satisfactory killing powers.

Vitamin D Milk Investigations. (L. R. Parkinson and F. P. Griffiths.) During the past year approximately 150 samples of commercially produced milk have been assayed in order to check the efficacy of various methods of vitamin D fortification in providing a milk of desired vitamin D content. All samples tested were satisfactory and the results indicated that the methods of vitamin D fortification of milk can be relied upon to produce a satisfactory product.

Fortification of Apple Juice Concentrate with Ascorbic Acid. (F. P. Griffiths, M. J. Garvey, and J. J. Powers.) Fortification of canned apple juice with ascorbic acid has been practiced in Canada for some time. Because fresh citrus fruits are not always available and are often high priced and because canned citrus juices are restricted under point rationing, the practicality of administering ascorbic acid to infants using apple juice concentrate as a carrier was studied.

Fresh apple juice was practically neutralized and concentrated six – to sevenfold. (If the juice was to be concentrated more than six-fold, it was de-pectinated before concentration to avoid jellying.) The hot concentrate was filled into gallon jugs to which had been added approximately one-half ounce of synthetic ascorbic acid. The added ascorbic acid very decidedly lightened the color of the concentrate and thereby improved its appearance greatly. Over a three months' storage period only a minor loss of vitamin C was noted. When the concentrate was diluted to its original volume for use, the antioxygenic effect of the added vitamin C on the color was still evident, although, of course, to a much less degree.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Julia O. Holmes in Charge

The Effect of Institutional Cooking Methods on the Vitamin Content of Foods.

I. The Thiamine and Ascorbic Acid Content of Potatoes. (A. W. Wertz and C. Edith Weir.) The potatoes were of the Green Mountain variety, grown in the Connecticut Valley, and were obtained from the college dining hall which served 750 Army Air Corps cadets. They were sampled at the following stages: (1) pared, (2) soaked 6 hours, (3) steamed one hour at 225°F., (4) mashed, (5) steamed and held in a steam oven 1½ hours at 157°F., and (6) mashed and held for 1½ hours at 157°F.

Of the total thiamine, 5 percent was lost during soaking, 15 percent during steam cooking, and 5 percent during the 1½ hour holding period between cooking and serving. Mashing did not appear to destroy thiamine. Of the vitamin C, none was lost during soaking, 54 percent was destroyed during steam cooking, 20 percent during mashing, and 10 percent during the 1½ hour holding period. The over-all loss in the mashed potato held 1½ hours before serving was 88 percent.

On the basis of the data obtained in the study, it is of interest to estimate the value of the potato in relation to man's requirement for thiamine and ascorbic acid, using the amounts of potatoes suggested by the Bureau of Home Economics for a low cost, a moderate cost, and a liberal diet for a very active man; i.e., 1.1, 0.9, and 0.9 pounds daily. Thus the whole or the mashed potatoes would have contributed 16, 13, and 13 percent respectively of the daily requirement for thiamine. The whole potato held 1½ hours before serving would have contributed 25, 21 and 21 percent respectively of the 75 mg. allowance for ascorbic acid, whereas the potato mashed and held 1½ hours before serving would have supplied only 11, 9, and 9 percent of the allowance. Had the potatoes been eaten immediately at the end of the steam-cooking period approximately 1/3 of the daily allowance would have been supplied by the above quantities of potatoes. The individual who consumes no more than an average-size portion of potatoes, cooked and mashed in large quantity, should probably discount the potato entirely as a source of ascorbic acid.

II. The Losses of Certain Vitamins in Beans. (A. W. Wertz, B. V. McKey, K. O. Esselen, E. Fuller, and J. O. Holmes.) The beans used in this study were obtained from the Massachusetts State College dining hall which served approximately 750 Army Air Corps cadets. This food was selected because of the frequency with which baked beans appear, not only for these cadets but also in many New England institutions and restaurants. Moreover, the bean is reputed to be a good source of the B-vitamins. The beans were analyzed (1) raw, (2) soaked, and (3) baked, following the addition to the parboiled beans of a mixture of molasses, tomato puree, and brown sugar. The analyses included thiamine, riboflavin, nicotinic acid, and pantothenic acid.

The soaked and drained beans had the same thiamine content as the raw dried beans. During the baking, however, three-fourths of the original content of thiamine in the beans–molasses mixture was destroyed. Raw beans are rich in thiamine; one-third cup of dried beans, equivalent to 1 cup of baked beans, contains approximately 0.4 mg. of thiamine or 22 percent of a moderately active man's daily thiamine allowance of 1.8 mg. One cup of baked beans, however, would contribute only .11 mg. or 6 percent of the daily allowance.

Riboflavin was not lost during either the soaking or the baking of the beans. In addition, the molasses–tomato–sugar mixture, added before baking, contributed almost as much of the vitamin as was in the raw bean. The baked beans, therefore, were richer in riboflavin than the raw beans. Even so, the baked beans were an extremely poor source of riboflavin; one cup of them would have supplied only 0.16 mg. or 0.6 percent of a moderately active man's daily allowance.

Approximately 11 percent of the nicotinic acid was lost during the soaking of the beans and another 11 percent during the baking. The baked beans were only a fair source of nicotinic acid, one cup contributing 1.2 mg. or 7 percent of a moderately active man's allowance.

During the soaking of the beans approximately 20 percent of their pantothenic acid was lost. At the end of baking, the beans had 18 percent less pantothenic acid than did the raw beans, although considerable of this vitamin was added in the molasses mixture. The baked beans contained 0.15 mg. pantothenic acid per cup.

III. The Losses of Certain Vitamins in Fish. (A. W. Wertz, B. V. McKey, K. O. Esselen, E. Fuller, and J. O. Holmes.) The fish were cut into serving portions, rolled in crumbs, seasoned, and baked 30–40 minutes at 450°F. When the fish were browned, moisture was added in the form of water, milk, or tomato puree in portions of 1 pint to 12 to 15 pounds of fish.

Forty-four percent of the thiamine was lost in the baking process. Some of the cooked fish were a poor source of thiamine, cod being the poorest. Cod, haddock, cusk, and pollock were found to contain between .011 and .062 and mackerel between 0.14 and 0.21 mg. of thiamine per one-fourth-pound serving portion. Whereas the mackerel would supply approximately 10 percent of a man's requirement for thiamine, those species related to the cod would supply only from 0.6 to 3 percent.

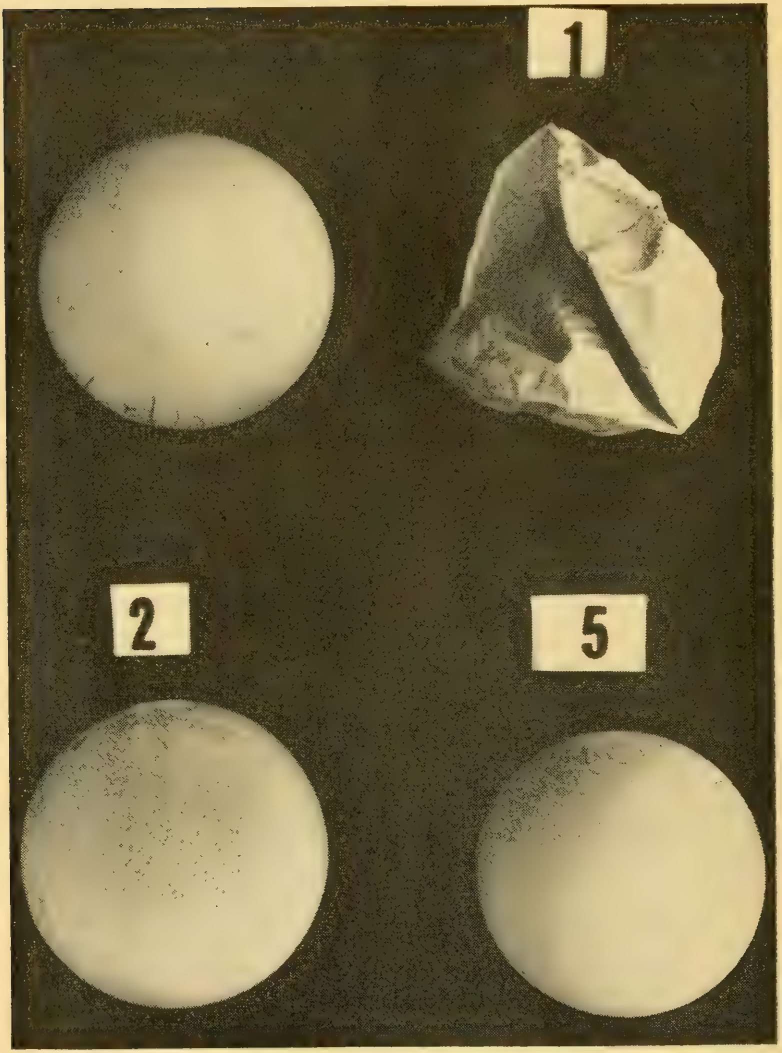
Of the 18 lots of fish studied, 11 lost riboflavin during baking, the average loss for these 11 approximating 28 percent. The mackerel contained more riboflavin, 0.5 mg. per 4-ounce serving, than did cod, cusk, haddock, pollock, and flounder, which averaged 0.12 mg. riboflavin per serving. The mackerel, in contrast to the other fish studied, is therefore a good source of riboflavin, and a moderate-sized serving of it will supply approximately one-fifth of the day's requirements for this vitamin.

During the baking process the average loss in nicotinic acid in fish was 29 percent. As was true for thiamine and riboflavin, mackerel contained appreciably more nicotinic acid than did the other species studied; 9.1 mg. per 4-ounce serving in contrast to 2.5 mg. for the others. Since the daily allowance of nicotinic acid for a moderately active man is 18 mg., it is obvious that a small serving of mackerel will supply half of it.

One-third of the pantothenic acid in the raw fish was destroyed during baking. In a 4-ounce serving of baked fish, mackerel had the largest quantity of this vitamin (4.6 mg.), flounder contained 2.4 mg., and those species related to the cod contained the least (1.7 mg.).

Dietary Factors Influencing Tooth Decay. (J. O. Holmes and L. R. Parkinson.) Massachusetts leads all other states in the incidence of tooth decay. Since human experience teaches that tooth decay can be inhibited by diet, this study was undertaken in an attempt to shed light on the dietary factors concerned. Rats were used as the experimental animals. They were fed a diet composed predominantly of coarsely ground corn. The hard particles cause fracturing of the teeth and enamel thereby presumably providing a surface susceptible to decay. In this respect the initiation of tooth decay in the rat apparently is not comparable to that in man. In addition to the basal diet various substances were fed; namely, cod-liver oil, sodium fluoride, vitamin K, the amino acid, cystine, a solubilized liver fraction containing several vitamins, the filtrate fraction of the vitamin-B complex containing several of the B vitamins, and the following individual components of the vitamin-B complex, choline, folic acid, para amino benzoic acid, biotin, pantothenic acid and inositol. Judged by the number of teeth wholly or partially missing, all of the diets allowed tooth destruction. However, fewer teeth were missing in the rats fed either fluorine or the filtrate fraction of the vitamin-B complex. The diet conducive to the greatest destruction of the teeth was the one containing choline. Examination of the teeth for small cavities has not been made as yet; such an examination is necessary before final conclusions can be made.

Calcification of Eggshell. (Marie S. Gutowska and Carl A. Mitchell.) Since poultrymen occasionally find soft-shell eggs, this study was undertaken to determine the factors concerned with the deposition of calcium carbonate onto the eggshell membrane. Phosphatase, the enzyme responsible for calcification of bone, apparently plays no role here. Proof that the enzyme concerned is carbonic anhydrase was obtained from two sources: (1) from data showing a higher content of this enzyme in the shell gland of layers than of non-layers and of layers of strong-shell eggs than of layers of soft-shell eggs; (2) from data obtained by injecting into laying hens sulfanilamide, which has an inhibiting effect on carbonic anhydrase activity. By varying the dosage, shells were produced with varying degrees of thickness, ranging from a thin soft membrane to a thick, chalky shell (see cut). The thickness of the shell varied directly with the level of carbonic anhydrase in the shell gland following the sulfanilamide injections. The carbonic anhydrase in the shell gland apparently acts as a catalyst in releasing from the blood carbonate ions, which, in turn, unite with the calcium of the blood to form calcium carbonate. The developing egg probably does not play an active role; its slight alkalinity provides a favorable environment for the precipitation of the calcium carbonate onto the membrane as the egg passes through the shell gland.



Effect of Sulfanilamide Injection on the Calcification of the Eggshell.

(The eggs are shown from their blunt end.)

Unnumbered--Smooth egg before injection.
1--soft-shelled egg 1 day after injection.
2--rough-shelled egg 2 days after injection.
3--smooth-shelled egg 5 days after injection.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Factors Influencing the Rapidity of Growth of Nursery Stock. (C. J. Gilgut, Waltham.)

Evergreens. Carolina hemlock and Canada hemlock grew better when given light applications of complete fertilizer than when given heavy applications. More new growth was obtained from 1/3 to 1/2 ton per acre of 5-8-7 broadcast among the plants than from one ton or more used in the same way. The heavier application, in many cases, actually injured the plants and injury was in the nature of stunting, poor growth, or dead tops. Mixed fertilizers such as 10-8-7 which contain a high percentage of nitrogen produced no more growth than did the 5-8-7 when used at the same rate, and sodium nitrate at 300 pounds per acre caused some injury, indicating that hemlocks do not need much nitrogen.

Deciduous Shrubs. Rooted cuttings of the hybrid lilac *Ludwig Spaeth* lined out in the field and given fertilizer treatments grew to salable size by the end of the second season as did those which received no fertilizer. There was no significant difference in growth and thriftiness of the plants which received fertilizer and those which did not. Fertilizing lilacs in the nursery to speed up growth is not advisable, especially when they are grown in a fairly good soil.

Factors Influencing the Hardiness of Evergreens. (C. J. Gilgut, Waltham.) Conditions favorable to winter injury of ornamental woody plants were present in the winters of 1942-43 and 1943-44 and offered a fine opportunity to determine the effect of cultural and fertilizing practices on winter hardiness of *Taxus cuspidata*, *Taxus canadensis stricta*, and *Taxus baccata repandens*.

The winter of 1942-43 provided the low temperatures which are considered one of the causes of winter injury. Several times the temperature went down to −15°F. and in addition there were prolonged periods of cold. During most of the winter there was a good cover of snow.

The winter of 1943-44 was quite different in that it was much milder and there was very little snow. The temperature went down to −3°F. only twice and even then for only a few hours. Most of the time it was well above zero, and from February on there were warm spells with strong drying winds—a condition which causes much winter drying, especially of evergreens.

During both winters the amount of injury was slight on the plants in the experiment. There was as much injury on plants which grew slowly and produced hard growth as on those which were stimulated with nitrates and fertilizers and produced soft growth.

Study of Herbaceous Perennial Material. (C. J. Gilgut, Waltham.) The herbaceous perennial test garden continues to be popular with visitors some of whom visit regularly, as often as twice a week throughout the summer. To the plants of recognized garden value and easy culture, new introductions and reintroductions of older plants little known to the general public are constantly being added. During the past summer 78 such new acquisitions were placed in the garden to determine their cultural requirements, habits of growth, garden value, and hardiness under the climatic conditions of this region. The collection now consists of about 1680 plants. Reports of the behavior of these plants are available to nurserymen and plantsmen, and are of assistance to them in deciding whether a new introduction is worth disseminating and what plants can best be dropped from catalogues.

The winter of 1943–44 was unusually severe on perennial plants many of which were killed in spite of a hay mulch. Severe damage occurred on Iris, particularly the hybrids with California parentage, and on hybrid Chrysanthemums of which more than 50 percent were killed outright.

DEPARTMENT OF OLERICULTURE

G. B. Snyder in Charge

Spraying Tomato Flowers with a Growth Hormone in the Greenhouse. (W. H. Lachman and G. B. Snyder.) Tomato flowers of the Waltham Forcing variety were sprayed during the winter months with a solution of orthochlorophenoxypropionic acid, 50 mg. per liter of water. The effect of this material was marked, for the ovaries of the sprayed flowers were twice as large as those of the unsprayed flowers at the end of three days. The fruits from the sprayed flowers were seedless for the most part, and the yield was markedly greater from these clusters than from the clusters of unsprayed flowers.

The Carotene Content of Carrots. (W. H. Lachman.) Seven varieties of carrots were analyzed for carotene during various stages of maturity as well as after they had been in cold storage at 32°F. for five months. Each of the varieties increased in carotene content with each successive sampling up to the time of harvest, which was November 1, 1943. The remaining roots were placed in a cold storage room where they were kept until April 1, 1944. The roots were again analyzed for carotene and the varieties were all found to be appreciably higher in carotene than before they were placed in cold storage.

The Effect of Mulching Staked and Pruned Tomatoes. (W. H. Lachman and G. B. Snyder.) Mulches of straw, manure, and sugar cane fiber were applied to the soil of plots in which staked and pruned tomatoes were grown. The mulches entirely prevented weed growth so that cultivation of the plots was not necessary. The mulches have increased the moisture-holding capacity as well as the organic matter content of the soil over the plots without any treatment. The yields and quality of fruit from these plots, however, do not show any significant differences. Cracking of the fruit has been largely responsible for lowering its quality, but it is evident that mulching has little effect on this factor.

Asparagus Investigations. (Robert E. Young, Waltham.) The work with asparagus consists of a breeding project in which individual production records have been obtained from 450 plants. This group of plants is made up of five selected strains from previous yield trials and one commercial variety. This is the fifth year that these plants have been harvested. The two best strains continue to produce about twice as much weight as the commercial variety.

There were some changes during the year and the yields were not as great as last year, the decrease amounting to 18 percent. The reduction in yield was not uniform for the six lots. For the highest producing strains the loss was 19.0 percent, and for the next highest 24.7 percent. The commercial variety, which was one of the poorest producers, lost only 15 percent.

The lower yields obtained for the year were due almost entirely to a smaller spear size because the total number of spears produced was about the same as the year before.

There seemed to be considerable change in the behavior of individual plants. Of the 50 best producing plants in 1942 about half remained in that category this year. Of the 50 best plants in 1943, half had increased their yield while the others yielded less than previously.

The rust disease which was so general in 1942, and had been increasing for the last few years, failed to show up even on the most susceptible plants.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.) During the year breeding work has been conducted with greenhouse cucumber, Summer Pascal celery, rutabaga, greenhouse lettuce, New York type lettuce, broccoli, carrot, and tomato. While progress has been made in developing strains of broccoli, carrot, and tomato better adapted locally, it is insufficient to justify detailed discussion.

Greenhouse Cucumber. The work of breeding a greenhouse cucumber has been projected along two lines. The first method has been to self-pollinate the best strains or varieties obtained from local growers. These strains originally varied considerably because the seed had always been mass-produced. Selfing has made them sufficiently uniform for extended trials with the growers.

In the second method of breeding, hybrids made by crossing these selfed lines were used. Yield trials with this material have been restricted by lack of greenhouse space. In the spring of 1943 the average yield of four hybrids over their respective parents was 11 percent. With better seed lines in 1944, the increase was 30 percent. Certain combinations of selfed lines were much better than others, such as hybrid M x A which was 35 percent better than the parents; A x H was 7 percent better; and H x W, 50 percent.

While it will take time to determine the proper combinations necessary for best yields for spring and fall, and under different types of pruning and training, the hybrid vigor is such as to make it desirable to place this material in the hands of growers for further testing. Moreover, the hybrids have produced an increase not only in yield but also in the percentage of No. 1 fruit, which is very important. To determine the best methods of producing hybrid seed, and the cost, has now become a part of this investigational work.

Greenhouse Lettuce. The crosses of Bel May X Cheshunt Early Giant were judged sufficiently uniform to be given a trial by growers before final fixing. The new variety has been named Waltham Early Forcing. In comparison with Bel-May it grows faster, has a darker green color, better development of the leaves on the bottom, and bolts to seed more slowly. Waltham Early Forcing plants are smaller than Bel-May, and the overlap of the leaves of the head is not so good.

Tests are now being conducted by growers in greenhouse and hotbed. The results of these tests will be used to determine whether the variety has sufficient merit to justify further work.

Lettuce, New York Type. (Cooperation with U. S. Bureau of Plant Industry.) The work with this crop has progressed to the point where two of the selections are ready for trial by growers. The first strain is one that has been selected for several years. It came originally from Dr. Whittaker of the U. S. Department of Agriculture, La Jolla, Calif., and is the same hybrid material from which Great Lakes was selected. Under our conditions the selection produced 90 percent marketable heads, as compared with 67 for the Great Lakes. There are some differences in the shape of head and character of the leaf but, in general, it resembles Great Lakes.

The second selection being made ready for trial is one from segregating material provided by Dr. Thompson of the U. S. Bureau of Plant Industry, Beltsville, Md., and involves a cross between Cosbia and Imperial 847. It is a good green color, does not tipburn readily, and is slow bolting. The leaf type of this strain is quite different from most lettuce. The local adaptation value of these two strains can be determined only by large-scale plantings by growers.

Summer Pascal Celery. The results of a breeding program to improve Summer Pascal celery by selection of single plants have shown that this variety is so homozygous in most characters that the population of the single plants cannot be distinguished from each other. Therefore, any further changes which are desired in this variety must be made by hybridization.

In anticipation of this, crosses were made between Summer Pascal and Cornell No. 19, and the second generation was grown as a spring crop. Prolonged cool weather at setting time caused some seed stalk formation: 100 percent in Cornell No. 19, 30 percent in the hybrid, and none in Summer Pascal. The redistribution of the various characteristics in the hybrid was such as to provide plants with almost all the desired points, and seed is being obtained for further trials.

Summer Pascal celery when grown at the Waltham Field Station has been short, with a total height of 20 inches; but the distance from the base to the first joint of the leaf stalk is rather long, 8.3 inches. This compares with Golden Plume which is 22.3 inches tall and 7.11 inches to the first joint. Cornell No. 19 is rather tall, with plants 22.3 inches and 8.6 inches to the first joint. Many of the hybrid plants were 11 to 11.5 inches to the first joint with plants 22 to 23 inches tall. Increasing the length of the stalk without increasing the height of the plant produces heavier celery with a larger percentage edible.

Rutabaga or Cape Turnip. During the past two years three strains of rutabaga were sent out to selected growers in Bristol and Barnstable Counties for trial. As a result of these trials, growers in Bristol County have selected the No. 1 white rutabaga as being more desirable than any variety previously available. In that section there are large plantings of this crop, mostly of the white flesh type. Because of acceptance of the variety in that area, it has been named Bristol White. This variety has foliage similar to Macomber, a white or very light purple shoulder that is unusually smooth, a short neck, and very few roots on the side. The white shoulder and smooth skin are contributing factors for good market appearance. Bristol White was developed as a white shoulder segregate from a green shoulder, white flesh Cape turnip.

Another strain given trial at the same time as the Bristol White is one having yellow flesh and green shoulder instead of the usual purple. It has been named Waltham Yellow turnip, and is considered of sufficient merit to justify further trial in sections that grow the yellow flesh type. This also is a segregate out of a White Cape strain. The flesh is a light yellow color and growth is typical of the White Cape turnips.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and L. Southwick.) The stock beds were continued and yielded a fair crop of rooted layers. Most of these were sold to nurserymen for establishing new stock beds. Dwarfing and semi-dwarfing rootstocks are in short supply and there is need for a substantial increase in establishing stock beds.

The orchard of 900 trees planted in 1939 has suffered from magnesium deficiency during the last three seasons. This is being corrected and at the present writing the trees are growing vigorously. Many of the trees bloomed in the spring of 1944, but the frost of May 19 ruined the crop except in the more elevated part of the orchard.

Trees on semi-dwarfing rootstocks are in demand by commercial growers who do not like tall trees. They will give acre yields equal to or higher than trees on seedling rootstocks, and growing and harvesting costs should be less.

One new cooperative orchard was planted in the spring of 1944.

Lethal Incompatibilities Between Clonal Stocks and Varieties of Apples. (J. K. Shaw and L. Southwick.) A paper reporting the results in 1943 appears in the Proceedings of the American Society for Horticultural Science, Volume 44. The combinations of the rootstock Spy 227 with various strains and varieties developed in the spring of 1944 as had been anticipated from their condition last fall. Shotwell Delicious, Paragon (Iowa strain), "Paragon L," Yates, and three strains of McIntosh are making normal growth; Blaxtayman is growing but is below normal; Stayman, Stamared, Winesap, Delicious, Starking, Richared, Golden Delicious, Arkansas (Mass. strain), Mammoth Black Twig (Iowa strain), Turley, Arkansas Black, and five strains of McIntosh including Blackmack are dead or dying. "Paragon L" is an unknown variety resembling but distinct from Arkansas and Paragon. A few Spy 227 stocks budded to strains that have failed, on which the bud failed to start, are now dead; while a few on which the bud of a successful strain failed to grow have put out new growth. Apparently the roots of Spy 227 budded to the "lethal" strains are dead or nearly so, and this root failure is the reason for the death or decline of the trees.

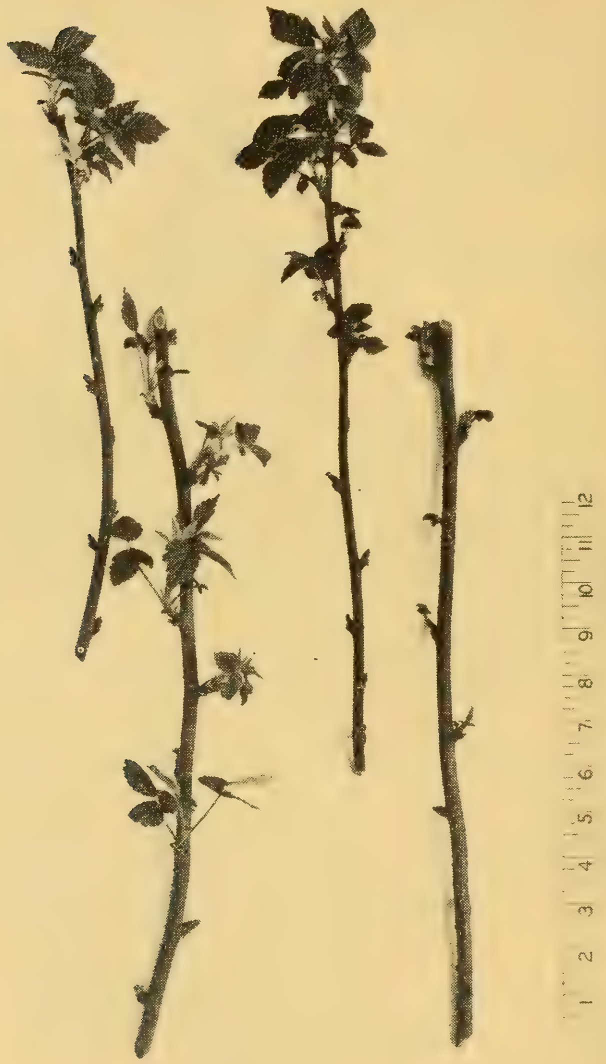
Winesap, Stayman, and one of the McIntosh strains, all of which fail on Spy 227, are growing vigorously on the two Spy 227 seedling clonal stocks, 227-2 and 227-12.

Study of Bud Sports of the McIntosh Apple. (J. K. Shaw and L. Southwick.) Several of the so-called bud sports fruited in 1943. These had all been selected on the basis of apparent variations of skin color of the apples. While slight differences in coloration were apparent, none were great enough to be of commercial significance. None of the distinctly striped strains fruited. This year's experience suggests that perhaps the selection of strains should be confined to the elimination of distinctly striped strains. Real evaluation of McIntosh strains awaits their performance in the orchard planted in 1941.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) Because of the severe winter of 1942-43, all peach buds were killed so that there was no crop and no field work could be done. It has been decided to terminate this project, and a final report is being prepared.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts and L. Southwick.) New varieties are being grown in the nursery for study in order that we may be familiar with them when found in commercial nurseries in the course of the usual nursery inspection service. One nursery was inspected for the first time in 1943, and, as is usual, more misnamed trees were found than in nurseries that have been examined for several years. The Massachusetts Trueness-to-Name Inspection Service now examines a large proportion of the nursery fruit trees grown in the northeastern part of the country and the number of misnamed trees reaching growers is very small.

A bulletin on plum varieties has been published.



Forced Half Canes of Raspberry, showing that starting of top buds is due to polarity not to difference in resting condition.

Nature of Winter Hardiness in the Raspberry. (J. S. Bailey, A. P. French, and R. A. Van Meter.) Shoots of six varieties of raspberry, Latham, Chief, Marcy, Taylor, Milton, and Washington, were brought into the greenhouse at monthly intervals during the winter and forced, to determine the length of the rest period. It is very short, ending in late November for a tender variety like

Marcy, and in early December for a hardy variety like Latham or Chief. Some shoots of Marcy, when brought into the greenhouse in late November had very immature terminals with leaves still attached. The buds on these terminals were easily forced into growth, making it look as if they had never gone into the rest period.

The terminal buds of raspberry canes commonly start first. To check the possibility that this is caused by a difference in the resting condition of the buds on the tip and on the basal half of the cane, canes were cut in half and the two halves forced separately. The fact that the top buds on the terminal and basal halves started equally readily (see cut) showed that the starting of the terminal buds is due to polarity and not to differences in rest period.

In winters when minimum temperatures are not below normal, there may still be considerable winter injury as in the winter of 1943–44. To see whether this injury is due to drying out and could be prevented by waxing the canes, a section of a row of each of the six varieties named above was sprayed with Dowax in the late fall. In the spring there was no difference in the amount of winter injury on the waxed and unwaxed canes, nor were there any consistent differences in moisture content of the canes. However, it is difficult to maintain a good wax coating on the canes, particularly the larger ones, the bark of which tends to split and peel off.

Estimates were made in the spring of 1943 and 1944 of the amount of winter injury to red raspberries, expressed as percentage of the total cane length injured. Results were as follows:

Variety	Percent Injury		Variety	Percent Injury	
	1943	1944		1943	1944
Sunrise	0	10	Cuthbert	25	60
Tahoma	5	10	Taylor	28	13
Indian Summer	5	5	Washington	30	31
Latham	9	8	Ohta	35	15
Ranere	10	10	Milton	44	18
Chief	11	6	Viking	45	70
Lloyd George	15	40	Marcy	68	63
Cayuga	20	5	Newburg	75	50

Controlled-Atmosphere Storage of Apples. (L. Southwick and O. C. Roberts, in cooperation with the Department of Engineering.)

1942–43 *Season*—The controlled-atmosphere storage room was filled (about 300 bushels) and closed on September 25, 1942. The oxygen was reduced to around 7 percent in two weeks' time, but it required seven weeks to reach 2 percent because of air leakage through the washer.

The McIntosh apples came out in fair to good condition on April 30, 1943. Although the characteristic aroma was lacking, as expected, the eating quality comprising firmness, crispness, juiciness, and flavor was superior to that of cold storage McIntosh. There is no doubt that the apples "kept" better and were less mature after 7 months in the controlled-atmosphere storage at 40°F. than similar apples in ordinary 32°F. cold storage. There was no regular storage scald but many apples were affected with a trouble which in appearance resembled soft scald but which probably was due to a lack of sufficient oxygen. On several occasions, and for periods of from one to several days, the oxygen level was below 2 percent and in two instances below 1 percent.

An experiment on the effect of date of harvest and pre-storage temperature following picking of McIntosh was conducted. Apples were harvested September 10, 15, and 21, and each picking was divided into three lots which were stored at 32°, 40°, and 50°F. to September 25, when all were placed in the controlled-atmosphere storage. All apples in the experiment came from a single tree. The main conclusions from this experiment follow:

1. Ordinary scald was not a factor except on apples picked early and held at 50°F. until placed in the controlled-atmosphere storage. From 90 to 100 percent of these scalded severely, but wrapping with oiled paper wraps controlled scald almost perfectly.
2. The soft scald type of injury (probably due to low oxygen) was more prevalent on the later picked fruit and in any particular lot on the more highly colored apples. There was no significant relation between incidence of this injury and the pre-storage temperature. Wrapping had no effect.
3. Judged by pressure tests and ground color, all apples had reached approximately the same stage of maturity by May 5, 1943, except those picked on the 10th and 15th of September and held at 50°F. These were riper.

1943–44 *Season*—The room was filled and sealed on September 30 and opened on March 27. The majority of the McIntosh apples were in excellent condition when checked after removal. Only an occasional apple showed the low-oxygen injury that was so prevalent the previous year, as special care had been taken to keep the oxygen level from dropping below 2 percent for any length of time. To compare the firmness of apples from air and controlled-atmosphere storage, flesh pressure tests were made on samples from each lot before and after storage. The apples in each comparison were harvested from the same tree. Average figures for 16 lots were as follows: on October 14, 10.06 pounds; on March 28, controlled-atmosphere stored apples, 9.01 pounds, and cold storage apples, 8.17 pounds. In every comparison, the controlled-atmosphere apples were firmer according to this pressure test. This difference was readily apparent in handling the fruit. Although the characteristic McIntosh flavor was lacking, the controlled-atmosphere stored apples were more crisp and juicy and in better condition for marketing then those stored in the usual way. Golden Delicious apples likewise were in good condition. Cortland scalded badly. No oiled wraps or shredded paper were used on any of the apples.

The Effect of Orchard Mulches on the Plant Nutrients in the Soil. (J. K. Shaw in cooperation with the Chemistry Department.) Soil samples were collected as in previous years and the orchard treatment continued. Analysis of the soil samples awaits the restoration of personnel absent in the war effort.

Blueberry Culture. (J. S. Bailey.) In cooperation with Professor W. L. Doran of the Department of Botany, a propagation experiment was carried out in which softwood cuttings of the variety Rubel were treated with various root-inducing substances. Several of these speeded rooting. Indolepropionic acid seemed particularly promising. The results of this work were reported in Massachusetts Agricultural Experiment Station Bulletin 410.

Until the summer of 1943, mummy berry had appeared only on a bush here and there in the Experiment Station blueberry planting. In 1943 considerably more appeared, enough to suggest that it may become a problem. An estimate of its severity on several varieties was made, using 0 for no infection and 10 for the heaviest. Results were as follows:

Wareham —10
Concord — 9
Rancocas — 8
Scammell — 6
Cabot — 5
Pioneer — 3
Rubel — 3
Pemberton — 2
Stanley — 2
Jersey — 2

In spite of the severe cold during the winter of 1942–43, blueberries were not severely injured. There was some injury to Cabot, both to the buds and wood. Injury to fruit buds of other varieties was very light. In spite of the cold winter, the 1.4 acres yielded 3800 quarts in 1943. The winter of 1943-44, although not extremely cold, was much harder on the blueberry plants; in fact, injury was the worst it has ever been at Amherst. A few plants were killed to the ground and a very considerable number had half or more of the wood killed. Injury was worst on stems 4 years old and older and on tender tips. There was little injury to vigorous young stems 3 years old or less. Also, it was noticeable that vigorous young shoots from stems 4 years old or older were injured much worse than the same type of growth from stems 3 years old or less. Injury to varieties from worst to least was as follows: Rubel, Number 73, Cabot, Scammell, Pioneer, Wareham, Pemberton, Stanley, Concord, Jersey. It was very unusual to have Rubel injured so badly, for this has been considered one of our most hardy varieties.

A severe frost on May 19, 1944, killed some tender tips of shoots and the margins of young leaves, and reduced the crop by perhaps 10 percent, although in many cases it was difficult to tell whether failure of berries to develop was due to winter injury or to the frost. It is estimated the 1944 crop will not exceed 20 percent of the 1943 crop.

Jersey continues to look more promising as a commercial variety. The fruit is large and very attractive, the quality is excellent if the berries are allowed to ripen, yields are high, and the bushes are very vigorous and appear to be winter hardy.

Wareham continues to produce large crops of large, fine-flavored berries, and ripens part of its crop after other varieties are all picked. However, it has two weaknesses which are serious enough to make its value as a commercial berry questionable: the berries crack badly after rains, and it appears to be very susceptible to mummy berry.

Some budded branches of a few U.S.D.A. seedlings produced a few berries for the first time in 1943. The fruit of F-72 is dark like Wareham but much larger. It is a little tart for eating fresh, but should make a good pie berry, for which purpose it was selected. It gives promise of being a heavy producer but had some mummy berry. It ripens late. R-86 has very attractive berries of a good blue color. Flavor is excellent, but size is not outstanding. It ripens late. U-85 is also late ripening. The berries are very large and attractive, but not quite so good in flavor as Pemberton. V-20 has berries as large as Pemberton or larger. Flavor is excellent when the berries are well ripened. The scar is large. It ripens late. GN-87 looked promising again in 1943. The berries are large, attractive, and of good flavor. The clusters were larger than previously, and, as a consequence, the berries were somewhat smaller. It promises to be a heavy yielder. Two possible weaknesses appeared: a large watery scar and some mummy berry.

Nutrition of the High-bush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) An experiment was set up in 1941 to test the effect of horse, cow, and poultry manure on cultivated blueberries. So far there has been no evidence of the toxic effect supposed to follow the use of manure. There was no significant difference in yield or size of berries which could be attributed to the kind of manure. A report of this work will appear in Volume 44 of the Proceedings of the American Society for Horticultural Science.

The difficulty of curing chlorosis by iron sprays or soil treatments indicates that some other element, perhaps potash, may be lacking. This is being investigated.

Preharvest Dropping of Apples. (L. Southwick.) Comparative tests with sprays and dusts for controlling the preharvest drop of apples were conducted in the late summer and fall of 1943. For the first time, dusts were used which contained higher percentages of active ingredients than the usual commercial dusts. The "regular" strength dusts were prepared so that one pound of dust was equivalent to ten gallons of a standard (.001 percent) spray in amount of active ingredient, while most of the more concentrated dusts used contained twice the amount. Standard and double strength sprays were included in the tests, and both dusts and sprays were used in single and in duplicate applications.

The fairly uniform success from all treatments in lessening preharvest drop of McIntosh was not entirely consistent with previous results which have shown better success with stronger sprays as well as with duplicate applications. Wider differences might have appeared had the harvest been delayed. Nevertheless, some of the data showed a slight trend toward better drop control with the double strength and the duplicate applications of both dust and spray. Therefore, further work is planned for the 1944 season. A report of the 1943 experiments will appear in Volume 44 of the Proceedings of the American Society for Horticultural Science.

Five new chemical compounds were tried in small-scale tests to determine their possible usefulness in controlling preharvest fruit drop. However, none of these materials in spray applications was comparable to napthalene acetic acid in effectiveness.

Beach Plum Culture. (J. S. Bailey.) A cooperative experiment was carried out with W. L. Doran of the Department of Botany on the propagation of beach plums by softwood cuttings. See the report of this work given on page 20.

As a result of the experience in 1942, the spray program was modified to get better control of the various diseases and insects. Slightly better results were obtained but the control of plum gouger was still poor. Careful search was made during the blooming seasons of 1942, '43, and '44, but no gougers were found. It is evident that this insect does not appear as early as had been reported. Limited preliminary tests of cryolite and of calcium arsenate sprays on beach plums were made in Amherst in the spring and early summer of 1944. No burning of the foliage has as yet resulted from the use of either material.

The failure of nearly the entire beach plum crop on the Cape in both 1941 and 1942 made it difficult to evaluate the effects of fertilizer treatments. Judging by the appearance of the plants and set of fruit (which later dropped off because of dry weather), a single application of 400 pounds per acre of a 5–6–4 cranberry fertilizer was better than the same amount split into 3 applications or than no fertilizer, although this application is probably too light to be very effective. Cottonseed meal used alone in 1943 gave slight evidence of benefit.

Because of lack of trained personnel to supervise the work, these experiments had to be discontinued in 1944. In their place outlines were prepared for grower cooperative experiments. These were distributed through the office of the County Agent, Mr. Bertram Tomlinson.

A more complete report of the beach plum work is in preparation.

Magnesium Deficiency in Massachusetts Apple Orchards. (L. Southwick.) It is now recognized that magnesium deficiency in apple orchards in Massachusetts is not limited to a few cases. Since the deficiency was positively diagnosed in 1942, it has been reported from most orchard sections in the state. Growth records in our young clonal stock orchard indicate the seriousness of this nutrient deficiency. The average increase in trunk cross-sectional area over a 4-year period shows that growth has been negatively correlated with severity of leaf scorch which is a principal symptom of magnesium deficiency.

Certain treatments designed to correct the deficiency were started in the fall of 1942 and continued in 1943. Four early-season spray applications of 2 percent magnesium sulfate (16 pounds of Epsom salts per 100 gallons of water) on young trees of several varieties gave commercial control of foliage scorch in 1943. Applications were made at approximately the dates for the pink, calyx, first cover, and second cover sprays.

Soil applications of Epsom salts, magnesium oxide, and kieserite, made in 1942, benefited young mulched trees in 1943 but not older bearing trees growing in sod. These materials were mostly broadcast on the soil under the affected trees in quantities varying from 5 to 15 pounds per tree. Magnesium limestone applied in amounts up to 50 pounds per tree was not effective. Other experiments likewise indicate that benefits from surface-applied limestone will be comparatively slow. Nevertheless, an important aspect of the use of magnesium limestone is its beneficial effect in reducing soil acidity as well as its capacity to prolong the effectiveness of the more soluble magnesium materials. A full report of the experiments will be published in Volume 44 of the Proceedings of the American Society for Horticultural Science.

Thinning Apples and Peaches with Caustic Sprays. (J. K. Shaw.) Experiments in thinning with caustic sprays were started in the spring of 1944 on Wealthy, Duchess, and McIntosh, also on several varieties of peaches. Comparisons were made of concentrations of from 1 to 3 pints of Elgetol in 100 gallons, of one and two applications, and of time of application as related to the development of the flowers. It is too early to draw final conclusions, but some preliminary statements may be ventured.

A spray of 2 pints to 100 gallons took off all or nearly all the fruits on moderately vigorous McIntosh.

Duchess trees were sprayed once, 2 pints in 100 gallons, on May 9, May 11, or May 12. All sprays were more or less successful. The spray on May 11, when practically all spur flowers were open and a few petals were falling, gave the best results. These trees need little or no further thinning. Wealthy trees, treated similarly on the same dates, when the flowers were less advanced, show no apparent results from the early spray and only partial thinning from the medium and late sprays.

Concentrations of from 1 to 3 pints in 100 gallons applied once (May 12) or twice (May 12 and 15) to Wealthy in another orchard gave varied results. Only the double spray, 2 pints in 100 gallons, seems to have thinned the fruits effectively. The weaker and the single sprays seem to have had more or less effect on the weaker trees, which are somewhat lacking in nitrogen, but all these trees require further thinning. Nearly all sprays were less effective on stronger trees which have been heavily mulched.

These preliminary observations suggest that McIntosh is easily thinned while Wealthy requires severe treatment, especially when the trees are vigorous and high in nitrogen. Duchess takes an intermediate position. Perhaps strong or double sprays should be used on trees known to have the habit of setting heavily, and weaker sprays on trees known to set only moderately.

Injury to the trees was less than expected. Measured by what is expected from pesticide sprays, it was rather severe; but the trees now look all right and perhaps the spray injury weakened the trees less than would the setting of an excessive crop. All these trees (except the McIntosh) have been distinctly biennial. Whether any of them will set a crop next year remains to be seen.

Sprays of 1 and 2 pints in 100 gallons applied to peach trees in full bloom were only partially effective. All trees required further hand thinning. The trees showed little injury.

Killing Poison Ivy. (L. Southwick.) In August 1943, ammonium sulfamate was applied to poison ivy growing under apple trees. With a small power sprayer, approximately 3 gallons of solution were required per large tree to wet thoroughly the rank ivy growth. Concentrations of ½, ¾, and 1 pound of the chemical per gallon of water were apparently effective in killing the ivy foliage. Recovery as of June 1944 is spotty, and the small amount of ivy that is growing does not have a normal or healthy appearance. However, on the basis of previous tests, a partial recovery in the season following applications indicates that additional treatment is required; if omitted, the ivy is very likely to continue to grow and increase. In general, the results seem to indicate that probably ¾ to 1 pound of ammonium sulfamate per gallon of water is an effective spray for poison ivy control.

The lower limbs of an apple tree were sprayed to observe the extent of injury. The sprayed foliage was killed inside of 24 hours and the killing later extended somewhat back from the sprayed portions. In other words, the chemical was evidently transported a short distance to unsprayed foliage and killed it. Although this does not seem to be a serious feature, care should be taken to keep the spray off the foliage of all fruit trees.

DEPARTMENT OF POULTRY HUSBANDRY

R. T. Parkhurst in Charge

Broodiness in Poultry. (F. A. Hays.) Attempts to establish a line of Rhode Island Reds that do not transmit the broody instinct have been greatly handicapped by the limited life span of the birds, by deferred broodiness, and by restricted numbers. The generation hatched in 1942 included 106 females sired by two 24-months-old males mated to hens with no record of broody manifestation. There was no evidence of broodiness in any of these daughters. The generation hatched in 1943 was also from aged parents and consisted of 81 daughters, which are now in their first laying year. They will be tested for deferred broodiness, which is probably the most important obstacle to overcome.

Effectiveness of Selective Breeding to Reduce Mortality. (Regional Poultry Research Laboratory, and Departments of Veterinary Science and Poultry Husbandry, Massachusetts Agricultural Experiment Station cooperating.) Records have been completed to the age of 18 months on all males and females hatched in 1942; to March 1, 1944 (about 11 months) on the 1943 generation; and to May 1 on the 1944 generation. Mortality rates for the first 6 months were decidedly lower in the low mortality line. Adult mortality from 6 to 18 months was significantly lower for females in the low line. Results for males were distorted by excessive cannabalism. The recessive lethal gene reported last year in the high mortality line appeared again in 1944 but to a lesser extent than in 1943.

Data for the 1943 generation from 6 to 11 months of age indicate that the incidence of diseases of the paralysis complex was not high in any of the lines. Cannibalism was the major cause of death; but no reason is evident why cannibalism should have been so much more prevalent in the high mortality line when birds of all lines were housed together. The data indicate further that selective breeding has increased longevity as measured by the age at death of birds in the high and low lines.

There is some evidence to indicate that inbreeding will uncover weaknesses that produce excessive mortality.

A preliminary report on the character of the lethal mutation that appeared in the high line in 1943 was published in the American Naturalist in 1944.

Genetic Laws Governing the Inheritance of High Fecundity in Domestic Fowl. (F. A. Hays and Ruby Sanborn.) Factors governing the inheritance of high intensity are less well understood than are the factors concerned in the inheritance of other characters affecting egg production. Recent studies have shown that intensity is the most variable character in our flock and that it bears an important relationship both to egg size and to number of eggs. The data indicate that intensity of laying responds to selective breeding.

Winter pause is governed both by genetic factors and by environmental conditions. Studies are being carried on to bring out the importance of inheritance in controlling this character.

Recent studies have been directed toward the possibility that other inherited factors, aside from the five well-recognized characters, may affect egg production.

A Study of Fertility Cycles in Males. (F. A. Hays.) The phase of this project concerned with the use of sex hormones in regulating male fertility was begun in the spring of 1944. Preliminary results indicate that sex hormones may be of value in stimulating spermatogenesis in males that are 36 months old, but not in younger males.

Physiological Relationships Between Molting Behavior and Fecundity Characters. (F. A. Hays and Ruby Sanborn.) Extensive data on molting behavior and results of selective breeding are available for six generations. One line was selectively bred for a short period of laying after the onset of annual wing molt. A second line was developed for the ability to lay for a long period after the onset of annual wing molt. The second line were superior producers.

A Genetic Analysis of Rhode Island Red Color. (F. A. Hays.) Two lines have been developed: the first, genetically late in sexual maturity; and the second, genetically early maturing. Differences in feather color between the two lines are being studied. Colorimeter studies of feather pigments indicate a multiple factor inheritance of feather color in Rhode Island Reds.

Miscellaneous Genetic Studies. (F. A. Hays.) The sex-linked gene E for early sexual maturity has been eliminated from some crosses between Barred Plymouth Rocks and Rhode Island Reds, to study the effect of autosomal gene E′ alone on age at sexual maturity. A line lacking both genes E and E′ has been established. Appropriate crosses have been made for these tests.

Progress has been made in separating the sexes of Rhode Island Red chicks on the basis of down color. A gold bar line that shows sex-dimorphism at hatching has been developed.

Ultra-violet light has not been effective to date in producing mutations in chickens.

The Value of Starfish Meal in the Poultry Starting Ration. (Raymond T. Parkhurst, in cooperation with Roy E. Morse and Francis P. Griffiths of the Department of Food Technology.) The commercially produced meal made by dehydrating starfish (*Asterias Forbesi*) can be satisfactorily used as a source of protein and minerals in chick starting rations.

Corn Distillers' By-Products in Chick Rations. (Raymond T. Parkhurst and Leonard E. Parkinson of the Nutrition Laboratory, in cooperation with Walter L. Nelson and Frances E. Volz, Schenley Research Institute, Lawrenceburg, Indiana.) Corn distillers' dried grains without solubles were used satisfactorily in the starting and broiler rations to replace ground oats and dried solubles, but not wheat bran and dried distillers' solubles. The feed efficiency was somewhat improved by the inclusion of corn distillers' dried grains without solubles; the difference in pigmentation and feathering was negligible.

Corn distillers' grains with solubles satisfactorily replaced dried skimmilk and wheat bran, wheat middlings, or ground oats in a starting ration for chicks, with an improvement in the feed efficiency.

Soybean oil meal with corn distillers' grains successfully replaced all the dried skimmilk, fish meal, and meat scraps in the starting ration.

Corn Distillers' By-Products in Laying and Breeding Rations. (Raymond T. Parkhurst in cooperation with Carl R. Fellers, Department of Food Technology, and John W. Kuzmeski of the Feed Control Service.) Three corn distillers' dried by-products — grains without solubles, grains with solubles, and solubles — were used as replacements in complete all-mash rations for Rhode Island Red and crossbred pullets in laying cages.

When the distillers' by-products replaced dried skimmilk pound for pound in rations containing either meat scraps or fish meal, there were no appreciable differences in egg production, feed consumption, feed efficiency, weight of egg, yolk color, open egg quality, egg shell texture, body weight changes, or mortality. Hatchability was not satisfactory when grains without solubles replaced dried skimmilk. Corn distillers' dried grains without solubles, when used to the extent of 10 percent in laying rations containing meat scraps, gave good egg production.

Corn distillers' dried grains with solubles, when used at the 10 percent level, with soybean oil meal and without animal protein supplements, proved satisfactory for egg production. When grains with solubles, up to 20 percent of the ration, were used to replace all the soybean oil meal and part of the ground barley and wheat bran in rations containing meat scraps but no dried skimmilk, egg production was satisfactory and the hatchability of fertile eggs was very good. With fish meal as a supplement, 5 percent of grains with solubles satisfactorily replaced either 2.5 percent of dried skimmilk or 3.5 percent of dried solubles.

Corn distillers' dried solubles, with soybean oil meal and without any animal protein supplements, proved of outstanding value for egg production. With fish meal as a supplement, satisfactory egg production and hatchability resulted when 3.5 percent dried solubles replaced 2.5 percent of dried skimmilk.

Corn distillers' by-products had no adverse effect on the weight of eggs, body weight gains, or egg quality as measured by shell breaking strength, height of albumen, and yolk color.

Fish meal proved a more valuable supplement for distillers' by-products than meat scraps for feed efficiency and hatchability. In combination with fish meal, equally good egg production and hatchability results were obtained when dried skimmilk was replaced by distillers' dried solubles, distillers' grains with solubles, or fermentation solubles.

Supplement for Distillers' Dried By-Products in Breeding Rations. (Raymond T. Parkhurst in cooperation with John W. Kuzmeski of the Feed Control Service.) In further studies with distillers' dried by-products, more evidence was obtained that fish meal contains one or more hatchability factors not yet identified and other than riboflavin, pantothenic acid, choline, or biotin. Hatchability was best in the groups of birds getting a ration containing 20 percent of milo-rye dried distillers' grains with solubles and flame-dried redfish meal, and poor in the groups of birds getting a similar ration without either meat scraps or fish meal.

Hatchability was excellent when birds were fed a ration containing milo-rye dried distillers' solubles at the 5 percent level, supplemented either with liver meal or with a combination of dried skimmilk, fish meal, and meat scraps at the same crude protein level. Poor hatchability was obtained from groups getting similar rations with no added animal protein, with or without dried brewer's yeast and/or cholrine chloride.

Methods of Feeding---Hatchability Studies. (J. H. Vondell.) Two pens of 70 Red females mated to 7 males were fed a complete all-mash ration; two pens of 70 Red females mated as above were hopper fed mash, whole corn, wheat, and oats; and 1000 eggs from each of the four pens were incubated in five lots. The complete mash ration gave 76.0 percent fertility and 88.7 percent hatchability of fertile eggs; the hopper feeding resulted in 78.3 percent fertility and 88.5 percent hatchability of fertile eggs.

Poultry Housing Projects, Winter of 1943-44. A. (C. I. Gunness and W. C. Sanctuary.) A non-insulated, two-thirds span, 20 x 20 pen was equipped with a special ventilating device consisting of a horizontal flue at the front of the house at floor level. From this a fan blew the air through a narrow slit over most of the litter and towards the rear of the pen. The intake to the flue drew in the warmer air from the point high in the pen, mixed with controllable amounts of fresh air admitted from out of doors. The net change of air was kept at a low point to maintain as high a room temperature as possible –within 2 to 5 degrees of similar adjoining insulated pens. The moisture content of the litter was about 13 percent higher than in the adjoining insulated pens ventilated by baffled window openings. There was but little condensation on the ceiling. There was little or no indication of discomfort to birds from the forced air current near the floor, in contrast to last year's test when a more rapid air flow was produced by use of a larger fan.

B. (W. C. Sanctuary.) Two 20 x 20 insulated pens were ventilated only with window openings equipped with baffle boards which deflected sharply downward all wind-driven incoming air. Provision for outgoing air was made by an ample space above the baffle device. Tests showed that the baffle increased the recirculation of warm air naturally set up in a typical laying pen by the body heat of the birds. Negatively the device prevented any direct drafts from blowing into the pen at a high level, which would neutralize or completely counteract the natural heat circulation, a result often observed in pens ventilated with the usual window openings. The hens' actions indicated no discomfort from the downward deflected air.

One of these pens had also a complete rearrangement of equipment. The nests were on the back wall. Indications are that heat from birds laying in the nests tended to increase the normal circulation over the litter from the front to the rear of the laying pens. Elevated pits 2½ feet forward of the nests and 30 inches from the floor prevented any floor drafts from the cellar sash openings in the rear wall near the floor (open in the summer) from striking the birds on their elevated perches. These pits held one month's droppings and proved easier to clean than floor pits, as well as obviating any danger of rotting out permanent floors or rear walls. The pits were equipped with an alighting perch which made it unnecessary to teach the pullets to go to roost. The water founts and non-wasting hoppers were elevated from the floor leaving practically the entire floor space free for birds and for the uninterrupted circulation of air. This arrangement materially increased the hens' working floor space, which should increase the laying house capacity substantially, an important objective.

The birds laid a few more eggs in the pen with the new housing arrangement. The moisture content of the litter was somewhat less even though this was an end pen, which made it more difficult to keep dry because of tracked in snow and moisture. The caking of the litter in the two pens showed a greater difference, being worse and more extensive in the pen equipped with the conventional dropping boards and floor hoppers, while in the specially arranged pen it was confined largely to the area around the water fount.

C. (J. H. Vondell and W. C. Sanctuary.) Birds in four pens in the new insulated house were fed two kinds of rations. Two pens received a ration consisting of three parts of mash and one part of grain. The other two pens were cafeteria fed mash and grain ad lib., the birds in this case eating less than 50 percent mash. It has been claimed that the feeding of all-mash or high-mash rations had no material effect on moisture content of litter. These tests proved the contrary to be true. On December 24 in the two pens where the birds ate a high percentage of mash, the average moisture content of litter was 48 percent (very wet); in the two pens with a low percentage of mash consumption, the moisture content of litter was 33 percent. The feeding method was then reversed, and by December 31 the moisture content of litter had changed with the feeding method, the new high-mash pen having 49 percent moisture and the new low-mash pen going down to 42 percent from the former 48 percent level.

Other pens, not in the test, where an all-mash ration was compared with a low-mash ration showed similar differences.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* A keen interest in pullorum disease testing has been noted during the past two seasons, particularly during the 1943–44 season when the volume of testing increased over the previous season by 142,459 tests. The trend in establishing and maintaining pullorum-free flocks continues to be highly favorable.

In view of war conditions, every possible effort has been made to meet this exceedingly great demand for testing. However, the strain on the laboratory facilities and personnel should not be of a permanent nature if the quality of the service is to be maintained at a high level.

Detailed reports of the two testing seasons are published in bulletins of the Control Series.

2. *Diagnostic Service.* This section of the report is based on the calendar year of 1943. A total of 3,674 specimens was received in 709 consignments, of which 377 were delivered in person. There was a sharp increase in the number of specimens and an all-time high figure for the laboratory was reached. This was perhaps due to the larger number of birds reared with less help and by inexperienced persons. The specimens were classified as follows: 3,228 chickens, 332 turkeys, 28 pheasants, 22 pigeons, 21 ducks, 11 rabbits, 9 each of foxes and swine, 4 canine feces, 3 bovine semen, 2 each of bovine organs, bovine feces, and guinea pigs, and 1 raccoon.

Coccidiosis (135), infectious bronchitis (73), tumors (67), pullorum disease (43), and so-called unknown disease (41) were the disease disburbances encountered most frequently. The tumors were classified on the basis of gross examination as follows: 44 lymphocytoma, 6 leukemia, 3 each of carcinoma and myelocytoma, 2 each of embryonal nephroma, hematoma, and unidentified; and 1 each of hepatoma, hemangioma, melanoma, myxoma, and thymoma. Avian tuberculosis was identified once and fowl typhoid twice. Fowl cholera was identified on 16 additional premises, bringing the total number of premises known to be infected during the past 10 years to 71. Fowl cholera was found in ducks and turkeys as well as chickens. A serious outbreak of avian tuberculosis was identified in pheasants on one farm. Subsequent investigation by representatives of the Bureau of Animal Industry, United States Department of Agriculture, revealed that over 90 percent of the old birds and about 6 percent of the young birds were infected.

A disease disturbance caused by coal tar, creosote, and anthracene oil was recognized in chicks. Chicks brooded from the time they are a day old in quarters recently treated with one of these products, may manifest trouble at about three weeks of age. The disturbance is similar to that observed in chicks fed rations containing excessive salt. Affected chicks may show retarded growth, ragged feathering, somnolence, difficult breathing, coughing, and moist tracheal rattling. Postmortem examination may reveal extensive edema of the subcutaneous tissues and the lungs, and an increase in fluid in the pericardial and body cavities. Cardiac enlargement, splenic atrophy, and sometimes pneumonia are observed. The kidneys and liver may vary in size but are usually swollen.

The 332 turkeys were received in 63 consignments. The diseases encountered most frequently were coccidiosis and enterohepatitis. Paratyphoid infection was encountered less frequently than formerly; whereas the number of cases of pullorum disease was the same as for the previous year. Disturbance due to a lack of vitamin A was recognized in birds of nearly marketable age. Two cases of fowl cholera were noted. Sinusitis, which had not come to our attention earlier, was identified in three cases. A serious outbreak of disease in one flock was identified as hexamitiasis.

3. *Flock Mortality Studies.* In a continuation of the work on the flock maintained at the College for genetic studies, 317 morbid and dead birds have been examined from the group hatched in the spring of 1942. There were 169 females and 148 males. The number of males examined was much higher than for any previous year, partly, no doubt, because of a greater effort to get all specimens to the laboratory.

The female population was sacrificed in January 1944 because of an acute outbreak of pullorum disease. This made only a minor difference in the records because only a small percentage of the population remained at the time of the outbreak, since the birds had completed their first laying year and had been disposed of in accordance with the usual practice. The origin of the pullorum infection was not established. The major portion of the infection was in a house containing birds, all of which were over 18 months of age. Repeated retesting of the remainder of the flock has failed to reveal additional infected birds.

Cannibalism was the primary cause of death of 54 females. Losses from cannibalism were particularly severe from March to August or during the period when the birds were over one year of age. Reproductive disorders (30), tumors and leukemia (26), fowl paralysis (14), and kidney disorders (11) were other important disease conditions noted. The incidence of fowl paralysis, which follows an erratic pattern in the flock, was less than one-third of that in the population of the previous year. The tumorous conditions were identified on the basis of gross examination as leiomyoma (9), lymphocytoma (8), myelocytoma (2), and miscellaneous (7).

4. *Salmonella Types Isolated.* Fifteen strains of paratyphoid organisms were recovered from consignments received from 11 poultry flocks and one herd each of swine and foxes. Eight *S. typhi-murium* strains were isolated from three chickens (including one mature bird), one fox, one turkey poult, and three adult pigeons. *S. tennessee*, *S. anatum*, *S. worthington*, and *S. bredeney* were isolated in one instance for each, the first two from poults and the last two from chicks. *S. bareilly* was recovered from specimens from the same premises on two different dates, one from a poult and the other from a chick. One of the *S. typhi-murium* strains was isolated from a poult from these premises also. *S. cholera-suis* var. *Kunzendorf* was recovered from a swine herd.

We are greatly indebted to Dr. Philip Edwards, Department of Animal Pathology, University of Kentucky, Lexington, Kentucky, who identified these strains as to type.

5. *Fowl Cholera in Ducks.* During the past year, a severe epornitic of fowl cholera occurred on a large duck farm in Massachusetts. No definite information could be obtained as to the origin of the outbreak, but during May 1943, the infection caused a sudden and heavy mortality in the flock especially among the ducklings. In some instances evidence of infection could be observed in ducks four to six weeks of age, but in many cases the heavy losses did not occur until the ducklings were eight to ten weeks of age. Losses varied among different hatches. The characteristic symptoms and lesions described for duck cholera were observed.

A special request was made to the laboratory for assistance in controlling this disease. Since autogenous bacterin has been recommended for the control of duck cholera, this laboratory agreed to produce and supply sufficient bacterin to inoculate the young ducklings that the owner planned to raise for the balance of the season. A total of approximately 25,500 ducklings hatched from June 25th to September 18th was inoculated. A total of 88,200 cc. of bacterin was supplied. Some lots of ducks received as many as four inoculations (2 cc. each) at approximately two-week intervals. No uninoculated controls were maintained. The mortality rate ranged from 3.3 to 79 percent for the different lots. As the season progressed the mortality rate declined, but with some fluctuation.

The owner was inclined to believe that the use of bacterin caused a reduction in losses. However, a critical analysis of the data did not justify such a conclusion. It was evident that in some lots the use of the bacterin failed to control losses, even though the first inoculation was made prior to signs of the infection.

Sulfathiazole was also tested as to its effectiveness in controlling active outbreaks of duck cholera. The limited data obtained suggested that this drug had little if any influence on the mortality of the disease. However, further experimentation is necessary to arrive at a definite conclusion.

The purpose of resorting to biologic therapy and chemotherapy was to aid the owner to finish his rearing season with as little loss as possible. The main objective was the elimination of the infection from the premises through a complete depopulation and sanitary program. At this writing, no evidence of cholera has been observed in young stock reared this season. However, sufficient time has not elapsed to permit a statement as to whether or not the infection has been completely eliminated.

6. *Infectious Bronchitis.* During the past year and a half the infectious bronchitis control work was extended to the majority of counties in the State. The Extension Service and the Division of Livestock Disease Control have continued to cooperate in this program. A total of 153 flocks was selected for the control project.

The production of virus material and the inoculation work were carried on in a manner similar to that of the previous year. The post-inoculation reactions were very favorable for the most part. In some instances no "takes" were obtained because the flock was immune as the result of previous exposure. Mild reactions which could not always be explained satisfactorily were obtained in some flocks. Severe reactions were observed when the flock was apparently in poor physical condition.

In November 1943 there were approximately 200,000 laying birds in the flocks which were considered protected against infectious bronchitis virus. The results of the past year further substantiate that birds immunized against infectious bronchitis during their pre-ovulation stage are able to resist natural infection to the degree that egg production is not interrupted. This crude but simple procedure for protecting commercial laying and breeding flocks against infectious bronchitis has met with great demand by the flock owners in the State. As the result of this interest, the work has been placed on a control service basis in order to execute the program more effectively. However, further research is necessary to improve methods of diagnosis of the disease, production of virus, and methods of inoculation of the virus.

7. *Farm Department Brucellosis Control and Eradication.* The laboratory tested 369 bovine and 27 porcine blood samples by the standard tube agglutination method during the past year.

WALTHAM FIELD STATION

Waltham, Massachusetts

Ray M. Koon in Charge

The members of the research staff of the Waltham Field Station are assigned to this branch by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Refer to reports of these departments for results of investigations conducted at this Station.

Soil Testing Service. Commercial vegetable growers, mushroom growers, florists, nurserymen, and vendors of loam brought in 2850 soil samples for testing and consultation.

There was a marked increase in the number of samples from home gardeners due to the activity of the Victory Garden movement. From 3835 individuals 5626 samples of soil were submitted, making a total of 8476 samples tested.

Testing Pressure Canner Gages. Aware that many pressure canners would be put into operation for food preservation, the Field Station offered to test the gages and safety valves. Of the 232 sent in only 85 were accurate. The remainder registered from 1 to 7 pounds too low or too high. Many of the safety valves were stuck and failed to blow off at pressures dangerous to the operator.

Field Day. Because of the shortage of gasoline and tires, the lack of farm machinery and other equipment for demonstration purposes, the annual meeting, which would have been the twenty-fifth, was not held.

PUBLICATIONS

Bulletins

398 Annual Report for the Fiscal Year Ending November 30, 1942, 64 pp. January 1943.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

399 Peach Growing in Massachusetts. By John S. Bailey. 16 pp. illus. January 1943.

Peaches have a limited adaptability to Massachusetts climatic conditions, and this deals with management practices essential for their successful production.

400 Breeding Snapdragons for Resistance to Rust. By Harold E. White. 16 pp. illus. February 1943.

Rust is a disease destructive to the ornamental value and seed productive capacity of snapdragons, and the results of attempts to produce resistant strains for greenhouse and garden use are here presented.

401 Plant Characters of Cherry Varieties. By A. P. French. 23 pp. illus. February 1943.

Considerable economic loss has resulted from planting cherry trees untrue to name. As an aid in the elimination of such a hazard, this bulletin directs attention to the characteristics by which nursery trees may be identified and records the important differences between the principal varieties.

402 Weather in Cranberry Culture. By Henry J. Franklin, H. F. Bergman, and Neil E. Stevens. 91 pp. illus. April 1943.

Weather plays an important role in cranberry culture. This is an attempt to interpret the influence of various weather conditions on this crop.

403 Descriptions of Apple Varieties. By J. K. Shaw. 187 pp. illus. April 1943.

The identification of fruit varieties before trees leave the nursery is important if disappointments in the orchard are to be avoided. These pictures and descriptions, including most of the apples now in common cultivation in America, are intended to help others to recognize these varieties and to serve as a record for future generations.

404 Home Dehydration of Vegetables. By S. Gilbert Davis, William B. Esselen, Jr., and Francis P. Griffiths. 24 pp. illus. April, 1943.

The emphasis on food conservation as a result of the war has aroused special interest in methods of preservation. The possibilities of home dehydration as a practical method are here presented.

405 Agricultural Finance in Massachusetts. By Sargent Russell and A. H. Lindsey. 39 pp. June 1943.

The general impression that Massachusetts farmers are heavily burdened with debt has a tendency to increase the cost of farm loans. This study was undertaken to determine the facts regarding this financial situation.

406 Feeding Urea to Dairy Cows. By J. G. Archibald. 166 pp. July 1943.

The scarcity of protein concentrates has created an interest in the use of urea as a partial substitute in dairy rations. Tests of its desirability are reported here.

407 Questions and Answers Concerning Pullorum Disease. By H. Van Roekel. 32 pp. illus. July 1943.

The purpose of this bulletin is to make available for the Massachusetts poultry industry information which will aid the poultrymen to improve their methods of establishing and maintaining pullorum disease-free flocks.

408 Home Refrigeration and Food Preservation. By John E. W. McConnell, William B. Esselen, Jr., and Carl R. Fellers. 19 pp. illus. July 1943.

With proper use an efficient household refrigerator reduces danger of the development of food poisoning organisms to a minimum and effectively preserves the quality and vitamin content of foods.

409 The Grape Plume Moth, with Notes on Other Pests of Grapes in Massachusetts. By W. D. Whitcomb, Wm. E. Tomlinson, Jr., and E. F. Guba. 20 pp. illus. October 1943.

Part I reports for the first time the complete life history and control by dormant spraying of the Grape Plume Moth, an obnoxious pest in home vineyards in eastern Massachusetts. Part II describes briefly other insects and diseases likely to attack grapes and includes a complete spraying and dusting schedule for their control.

410 Propagation of the High-Bush Blueberry by Softwood Cuttings. By W. L. Doran and J. S. Bailey. 8 pp. illus. November 1943.

Blueberries are difficult to propagate because the cuttings root so slowly. These experiments were planned to find a method for decreasing the percentage of failures encountered at present.

411 Variability in Egg Weight in Rhode Island Reds. By F. A. Hays. 16 pp. illus. January 1944.

Market grades of eggs are based largely on weight, and it is important, therefore, for the breeder to know how much variability in egg weight may be considered normal and how much is due to genetic factors.

412 The Cabbage Maggot. By W. D. Whitcomb. 28 pp. illus. February 1944.

The Cabbage Maggot is a destructive pest of cruciferous plants in Massachusetts, and successive crops can seldom be grown successfully without providing protection against it. The most satisfactory treatments to use on certain types of plants and for different degrees of infestation are recommended.

413 The Identification of Plum Varieties from Non-Bearing Trees. By Lawrence Southwick and A. P. French. 51 pp. illus. March 1944.

The identification of varieties before fruit trees leave the nursery is important if disappointments in the orchard are to be avoided. This bulletin considers the characteristics by which nursery plum trees may be identified and records descriptions and photographs of 57 varieties.

414 Bacteria and Rural Water Supplies. By James E. Fuller. 20 pp. June 1944.

This is an attempt to give intelligent direction to what constitutes sanitation in rural water supplies.

415 Sunflowers as a Crop. By Karol J. Kucinski and Walter S. Eisenmenger. 8 pp. illus. June 1944.

Sunflowers as a farm crop deserve consideration in Massachusetts because of their merits as a feed for poultry and other livestock in this area where adequate and satisfactory supplies of feed are of foremost concern.

416 Relation of Intensity to Egg Weight and Egg Production. By F. A. Hays. 12 pp. June 1944.

Intensity is one of the most important inherited characters affecting egg production. This study brings out important relationships between intensity, egg weight, and egg production in an improved flock.

Control Bulletins

116 Twenty-third Annual Report of Pullorum Disease Eradication in Masschusetts. By the Poultry Disease Control Laboratory. 11 pp. July 1943.

117 Inspection of Commercial Feedstuffs. By the Feed Control Staff. 16 pp. September 1943.

118 Inspection of Commercial Fertilizers and Agricultural Lime Products. By Fertilizer Control Service Staff. 26 pp. September 1943.

119 Seed Inspection. By F. A. McLaughlin. 63 pp. November 1943.

Meteorological Bulletins

649-660, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

Reports of Investigations in Journals

NUMBERED CONTRIBUTIONS

436 Relation of Weather Conditions to Onion Blast. By Linus H. Jones· Plant Physiol. 19 (1):139-147. 1944.

443 The Diagnosis of Avian Neoplasia. By K. L. Bullis and Carl Olson, Jr. Amer. Jour. Vet. Res. 4 (31):382-387. October 1943.

446 New Stabilizing Materials for Ice Cream. By A. M. Shipley, M. J. Mack and J. H. Frandsen. Canad. Dairy and Ice Cream Jour., vol. 22, no. 7. July 1943.

447 An Explanation of the Increased Efficiency of Gelatin in Ice Cream Mix when Initially Aged at 68°F. By W. S. Mueller. Jour. Dairy Sci. 26 (2): 189-204. February 1943.

450 Egg Production versus Reproduction in Rhode Island Reds. By F. A. Hays. Poultry Sci. 22 (2):118-122. March 1943.

451 Alkaline Phosphatase and Egg Formation. By Marie S. Gutowska, Raymond T. Parkhurst, E. M. Parrott, and R. M. Verburg. Poultry Sci. 22 (3):195-204. May 1943.

455 The Composition and Palatability of Some Common Grasses. By J. G. Archibald, E. Bennett, and W. S. Ritchie. Jour. Agr. Res. 66 (9):341-347. May 1943.

458 Soluble Chlorine in Feeding Stuffs. By John W. Kuzmeski. Assoc. Off. Agr. Chem. Jour. 26 (1):87-90. 1942.

460 Carbohydrates of the Ebenezer Onion. By Emmett Bennett. Food Res. 8 (4):273-274. 1943.

461 The Influence of Variety, Size, and Degree of Ripeness upon the Ascorbic Acid Content of Peaches. By G. M. Schroder, G. H. Satterfield and Arthur D. Holmes. Jour. Nutr. 25 (5):503-509. May 1943.

462 Magnesium Deficiency in Massachusetts Apple Orchards. By Lawrence Southwick. Amer. Soc. Hort. Sci. Proc. 42:85-94. 1943.

463 Comparative Results with Sprays and Dusts in Controlling the Preharvest Drop of Apples. By Lawrence Southwick. Amer. Soc. Hort. Sci. Proc. 42:199-202. 1943.

464 Inheritance of Mottled Earlobes and Stubs in Rhode Island Reds. By F. A. Hays. Amer. Nat. 77:471-475. September-October 1943.

465 Measuring Performance of Progeny of Rams in a Small Flock. By M. E. Ensminger, R. W. Phillips, R. G. Schott, and C. H. Parsons. Jour. Anim. Sci. 2 (2):157. May 1943.

466 Hay Mulches in Apple Orchards. By J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 42:30-32. 1943.

467 Experiments with Lima Beans. By William H. Lachman and Grant B. Snyder. Amer. Soc. Hort. Sci. Proc. 42:554-556. 1943.

468 They're Tops! By Emmett Bennett. Jour. Home Econ. 35 (5):288. May 1943.

469 Some Acidic Properties of Alkali Lignin. By Emmett Bennett. Soil Sci. 55 (6):427-431. June 1943.

470 The Effect of Cocoa upon the Utilization of the Calcium and Phosphorus of Milk. By W. S. Mueller and Marilyn R. Cooney. Jour. Dairy Sci. 26 (10):951-958. October 1943.

471 The Inheritance of an Agglutinogen of the Chicken Erythrocyte. By Carl Olson, Jr. Jour. Immunol. 47 (2):149-154. August 1943.

472 Relationships of Natural Vegetation to the Water-Holding Capacity of the Soils of New England. By Walter S. Colvin and Walter S. Eisenmenger. Soil Sci. 55 (6):433-446. June 1943.

473 Crab Meal in Poultry Rations. I. Nutritive Properties. By Joseph A. Lubitz, Carl R. Fellers, and Raymond T. Parkhurst. Poultry Sci. 22 (4):307-313. July 1943.

474 Identification of Certain Red and Purple Raspberry Varieties by Means of Primocanes. By O. C. Roberts and A. S. Colby. Amer. Soc. Hort. Sci. Proc. 42:457-462. 1943.

475 Laboratory Examination of Eating and Drinking Utensils. By Ralph L. France, James E. Fuller, and W. E. Cassidy. Amer. Jour. Pub. Health 33 (9):1054-1064. September 1943.

476 Small Dehydrators for Vegetables. By S. G. Davis, W. B. Esselen, Jr., and F. P. Griffiths. Food Indus. 15 (5):54-57; (6):53-55, 108-109. May and June 1943.

477 Manganese in Cows' Milk. By J. G. Archibald and H. G. Lindquist. Jour. Dairy Sci. 26 (4):325-330. April 1943.

478 The Ratio of Ascorbic Acid, Riboflavin, and Thiamine in Raw and Pasteurized Milk. By Arthur D. Holmes, Carleton P. Jones, Anne W. Wertz, and John W. Kuzmeski. Jour. Nutr. 26 (4):337-345. October 1943.

479 Sand Dune Stabilization on Cape Cod. By Karol J. Kucinski and Walter S. Eisenmenger. Econ. Geog. 19 (2):296-214. April 1943.

480 Uniformity of Riboflavin Content of Milk Produced under Standardized Conditions. By Arthur D. Holmes and Julia Holmes. Amer. Jour. Dis. Children 66:607-610. December 1943.

481 The Ascorbic Acid Content of Late-Winter Tomatoes. By Arthur D. Holmes, Carleton P. Jones, and Walter S. Ritchie. New England Jour. Med. 229:461-464. September 1943.

482 A Practical Method for Sterilization and Subirrigation of Soil in Flats. By Linus H. Jones and William L. Doran. Florists' Exch. and Hort. Trade World 100 (22):9 and 11. May 1943.

483 New Way to Subirrigate Flats. By Linus H. Jones. The Flower Grower 30 (9):430-431. September 1943.

484 Effect of Pasteurization on the Riboflavin Content of Milk. By Arthur D. Holmes. Jour. Amer. Dietet. Assoc. 20 (4):226-227. April 1944.

485 Methods for Quick Freezing and Dehydrating Mushrooms. By H. J. Brunell, W. B. Esselen, Jr., and F. P. Griffiths. Food Indus. 15 (11):74-75, 140-142. November 1942.

486 Some Anti-Oxidant Properties of D-iso Ascorbic Acid and Its Sodium Salt. By F. J. Yourga, W. B. Esselen, Jr., and C. R. Fellers. Food Res. 9 (3): 188-196. May-June 1944.

488 Crab Meal in Poultry Rations. II. Chick and Broiler Rations. By Raymond T. Parkhurst, Marie S. Gutowska, Joseph A. Lubitz and Carl R. Fellers. Poultry Sci. 23 (1):58-64. January 1944.

489 Light Has No Effect on Commercially Glass Packed Foods. By J. J. Powers, W. B. Esselen, Jr., and F. P. Griffiths. The Glass Packer 22 (8):-528-530, 554. August 1943.

490 Creosote Injurious to Plants. By Linus H. Jones. Horticulture 21 (22): 462-463. December 1943.

491 Zinc in Cows' Milk. By J. G. Archibald. Jour. Dairy Sci. 27 (4):257-261. April 1944.

492 Riboflavin Content of Immature Massachusetts Lettuce. By Arthur D. Holmes. Food Res. 9 (2):121-125. March-April 1944.

493 Crab Meal in Poultry Rations. III. Laying and Breeding Rations. By Raymond T. Parkhurst, Marie S. Gutowska and Carl R. Fellers. Poultry Sci. 23 (2):118-125. March 1944.

494 Range Utilization by Growing Chickens. By John H. Vondell. U. S. Egg and Poultry Mag. 49:464-466. October 1943.

495 The Vitamin A Content of Sheep's Colostrum and Milk. By G. Howard Satterfield, R. E. Clegg, and Arthur D. Holmes. Food Res. 9 (3):206-211. May-June 1944.

496 A second Note on the Propagation of Beach Plum by Softwood Cuttings. By W. L. Doran and J. S. Bailey. Amer. Nurseryman 78 (8):7-8. October 1943.

498 Chondrodystrophy in Rhode Island Reds. By F. A. Hays. Amer. Nat. 78:54-58. January-February 1944.

499 How to Make Dormant Cuttings. By W. L. Doran. The Flower Crower 31 (1):18-19, 49. January 1944.

500 Ascorbic Acid, Riboflavin, and Thiamine Content of Cow's Milk: Influence of the Ration. By Arthur D. Holmes, Carleton P. Jones, and Anne W. Wertz. Amer. Jour. Dis. Children 67:376-381. May 1944.

502 Some Results in Correcting Magnesium Deficiency in Apple Orchards. By Lawrence Southwick and J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 44:8-14. May 1944.

503 Further Results with Sprays and Dusts in Controlling the Preharvest Drop of Apples. By Lawrence Southwick. Amer. Soc. Hort. Sci. Proc. 44:109-110. May 1944.

504 Certain Scion Incompatibilities and Uncongenialities in the Apple. By J. K. Shaw and Lawrence Southwick. Amer. Soc. Hort. Sci. Proc. 44:239-246. May 1944.

505 The Influence of Venting on Pressure Cooker Performance. By William B. Esselen, Jr. Jour. Home Econ. 36 (3):143-146. March 1944.

506 A Comparison of Manures Applied to Cultivated Blueberries. By John S. Bailey. Amer. Soc. Hort. Sci. Proc. 44:299-300. May 1944.

512 Chlorine-Ammonia Treatment of the Water Supply of Amherst, Massachusetts. By James E. Fuller. New England Waterworks Assoc. Jour. 58 (2):89:100. June 1944.

UNNUMBERED CONTRIBUTIONS

"Green Gold." By J. G. Archibald. New England Homestead, April 8, 1944.

Soil Treated with Formaldehyde after Seeding to Control Damping-off. By William L. Doran. Agr. News Letter of E. I. du Pont de Nemours and Co. 11:3:47-49. 1943.

Wood Decay Fungi. (Wood-destroying organisms—Sec. X.) By Malcolm A. McKenzie. Rpt. Sixth Ann. Pacific Coast Pest Control Operators' Conf., Univ. Calif., February 3-5, 1943. pp. 47-48.

Municipal Tree Work in Massachusetts, 1943. By Malcolm A. McKenzie. Proc. 32d Ann. Meeting Mass. Tree Wardens' Assoc. and Moth Supt., Boston, February 4, 1943.

The Dutch Elm Disease Program in Massachusetts with Special Reference to the Manpower Problem. By Malcolm A. McKenzie. Proc. Northeastern Forest Disease and Insect Pest Conf., Boston, March 17. 1943.

Diseased Maples in Massachusetts. By Malcolm A. McKenzie. Plant Dis. Reporter 27:12/13. July 1/15, 1943.

Municipal Shade Tree Programs in Massachusetts. By Malcolm A. McKenzie. Arborists' News. Rpt. Natl. Shade Tree Conf., Boston, February 3, 1944.

Trees Adapted for Planting in Tree Belts. By Malcolm A. McKenzie. Proc. 33d Ann. Meeting Mass. Tree Wardens' Assoc. and Moth Supt., Boston, February 4, 1944.

Dutch Elm Disease. By Malcolm A. McKenzie. Rpt. New England Div. Amer. Phytopath. Soc., Waltham, February 23-24, 1944. p. 6.

Riboflavin. By Arthur D. Holmes. Apothecary, p. 8. April 1943.

What of Tomorrow if We Let Down Today? By J. H. Frandsen. Ice Cream Field, October 1943.

Milk Scoring Contest. By H. G. Lindquist. New England Goat News, October 1943.

Essentiality of Milk. By J. H. Frandsen. Amer. Milk Rev., March 1944.

Fruit Insects of 1942 and the Outlook in 1943, with Special Reference to Western Massachusetts. By A. I. Bourne. Ann. Rpt. Mass. Fruit Growers' Assoc. 49:45-48, 86, 1943.

State Summary of 1943 Orchard Pest Problems — Massachusetts. By A. I. Bourne. Amer. Fruit Grower, February 1943, p. 6.

An Unusual Type of Ethylene Dichloride Injury to Peach. By A. I. Bourne and J. S. Bailey. Jour. Econ. Ent. 36:470-471, 1943.

Spraying Home Fruit Trees. By W. D. Whitcomb. Horticulture 21:82-83, 1943.

Fruit Insect Problems in 1942 and How They May Affect the 1943 Program. By W. D. Whitcomb. Ann. Rpt. Mass. Fruit Growers' Assoc. 49:91-94, 1943.

Fruit Insect Problems in 1943. By W. D. Whitcomb and A. I. Bourne. Ann. Rpt. Mass. Fruit Growers' Assoc. 50:41-44, 1944.

What the Locker Plant Operator Should Know about Food Poisoning. By Francis P. Griffiths. Quick Frozen Foods 6 (5):45, 58. 1943.

Bigger Home-Canning Pack Looms for 1944. By William B. Esselen, Jr. The Glass Packer 23 (2):117-119. 1944.

Mimeographed Circulars

FM-11 Should Plowing Corn Lands be Mandatory under Massachusetts State Law? By Arthur W. Dewey. 10 pp. March 1943.

FM-12 Production Costs for Corn and Grass Silage. By Charles R. Creek. 9 pp. April 1943.

FM-13 Returns from Pasture Treatment. By Charles R. Creek. 19 pp. April 1943.

FM-14 Returns from Poultry Farming in Massachusetts in 1942. By Charles R. Creek. 23 pp. September 1943.

FM-15 Returns from Dairy Farming in Massachusetts in 1942. By Charles R. Creek. 11 pp. October 1943.

FM-16a Making Vegetable Farming Easier. By Charles R. Creek. 1 p. January 1944.

Ice Storm Damage May Promote Spread of Dutch Elm Disease. By Malcolm A. McKenzie. February 10, 1943.

Topics of Interest to Municipal Tree Wardens. By Malcolm A. McKenzie. June 1, 1943.

Ash Rust. By Malcolm A. McKenzie. July 2, 1943.

Extension Publications

The following Extension Leaflets and Circulars were prepared wholly or in part by Experiment Station men during the period covered by this report.

Winter Injury to Trees. By Malcolm A. McKenzie. Mass. State Col., Ext. Spec. Cir. 117 (mimeographed). May 1944.

Potato Growing. By A. I. Bourne and O. C. Boyd. Mass. State Col., Ext. Leaflet 20 (revised).

Recommendations to Cucumber Pickle Growers. By A. I. Bourne and O. C. Boyd. Mass. State Col., Ext. Spec. Mimeographed Cir. (revised).

Pest Control in the Home Garden. By A. I. Bourne and O. C. Boyd. Mass. State Col., Ext. Leaflet 171 (revised).

The Fungicide and Insecticide Situation. By A. I. Bourne and O. C. Boyd. Mass. State Col., Ext. Spec. Mimeographed Cir.

Vegetable Pest Control Chart (monthly revision). By A. I. Bourne and O. C. Boyd.

Pest Control Calendar for Potatoes (revised). By A. I. Bourne and O. C. Boyd.

Insecticides for the Control of the European Corn Borer in Early Sweet Corn. By A. I. Bourne and James W. Dayton. Mass. State Col., Ext. Cir. 76 (revised).

Re-use of Commercial Jars for Home Canning. By William B. Esselen, Jr. Mass. State Col., Ext. Leaflet 217. 8 pp. illus. April 1943.

Freezing Fruits, Vegetables and Meats for Home Use. By William R. Cole and Francis P. Griffiths. Mass. State Col., Ext. Spec. Cir. 103. 7 pp. mimeographed. June 1943.

Special Food Preservation Problems. By Francis P. Griffiths, William R. Cole, S. Gilbert Davis and William B. Esselen, Jr. Mass. State Col., Ext. Leaflet 226. 24 pp. 1944.

599141

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Jan. 16, 1945

Bulletin No. 418 August 1944

The Propagation and Identification of Clonal Rootstocks for the Apple

By J. K. Shaw

There is a demand, far exceeding the supply, for clonal rootstocks for growing dwarf and semi-dwarf apple trees. This bulletin tells how they are grown and how the different kinds may be identified, thus helping to keep these rootstocks true to name.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE PROPAGATION AND IDENTIFICATION OF CLONAL ROOTSTOCKS FOR THE APPLE

By J. K. Shaw, Research Professor of Pomology

There is now considerable interest in semi-dwarf and dwarf apple trees for the orchard and home garden. Such trees are produced by budding on certain clonal rootstocks. These rootstocks must be grown by cuttings or layers and are not available in sufficient numbers at the present time. Therefore, a discussion of their characteristics and methods of propagating them may be helpful.

Apple trees become dwarfed chiefly because of precocious fruiting. When much of the synthesized material from the leaves is used to produce apples, there is that much less for vegetative growth. This is the condition in mature bearing trees.

Dwarf trees commence production and mature earlier than trees on "standard" or "free" stocks. They form fruit buds at an earlier age because of some influence of the rootstock. It is not known just what this influence is, but some suggestions may be advanced. Fruit buds are formed in June and July. It is known that a restricted water supply and an accumulation of starch in the tree precede or accompany fruit bud differentiation. It has been shown that dwarfing rootstocks cease root growth earlier and that this lowers water absorption, also that the graft union restricts the passage of water, and that a greater accumulation of starch takes place in dwarf trees. It may reasonably be assumed that restricted water supply (and possibly nitrogen and other mineral matter) together with an accumulation of starch and possibly some other substance or substances are effective in forming fruit buds. And it is certain that fruit production is very effective in reducing rate of growth.

THE PROPAGATION OF APPLES

Seedling Rootstocks

The usual method of propagating apple trees is by budding or grafting the desired variety on seedling rootstocks. Seeds are obtained from various sources such as cider mills and canning factories. After a period of exposure to low temperatures under moist conditions, the seeds will germinate, and after one season of growth, the seedlings are transplanted and budded to the varieties desired, or the seedling roots may be whip grafted and set in the nursery. After one or more seasons of growth in the nursery, the trees are ready for planting in the orchard. Apple seedlings are extremely variable in vigor and growth habits, and it seems reasonable to expect trees budded or grafted on them to differ greatly in vigor and production. As a matter of fact, such trees are rather remarkably uniform insofar as stock effect is concerned. Most of the differences seen in the orchard are due to soil conditions, though injuries of various kinds sometimes result in inferior trees.

Seedling-rooted trees seem to be more variable in England and on the Continent than they are in America. Probably both seedlings and nursery trees are more rigidly graded here, thus eliminating weak trees before they are planted in the orchard. Climatic conditions here and in Europe differ and may cause differences in the variability of orchard trees. Trees on clonal rootstocks are much in favor in England largely because they are more uniform. The American orchardist who hopes to avoid poor trees in the orchard by the use of clonal stocks is likely to be disappointed. He may gain a little in uniformity but not much.

Clonal Rootstocks

Clonal rootstocks have been known for 200 years or more though they have never been used extensively. The objective has been the production of dwarf trees. A clonal rootstock may be considered to be a variety just as McIntosh is a variety. Both originated from single seedling trees and are propagated by asexual means such as budding, grafting, layering, or by cuttings; neither comes true from seeds. All individuals of a variety are genetically alike except in rare cases where a mutation or bud sport appears; practically all differences between individual trees are due to environmental influences.

The difference between clonal rootstocks and varieties is that varieties have been chosen because of superior fruit and tree characters which make them desirable for fruit production, while no attention is paid to fruit characters when selecting clonal rootstocks; they are chosen because they can be propagated readily by asexual means and for their effect on the varieties budded on them. It is possible that a good clonal rootstock or a good variety may appear in any lot of apple seedlings but in only an exceedingly small percentage.

The selection and propagation of clonal rootstocks has been going on in Europe for many years. The importation of these rootstocks to America began many years ago. About a dozen different kinds were known, but little was published about the different kinds and most of them were unknown in America. In 1912, Wellington of the East Malling Research Station in Kent, England, collected clonal stocks from stock growers in England and on the Continent for the purpose of studying them and their value as apple rootstocks. They were received under various names. It became apparent at once that the situation was very confused as to names and types. Many lots consisted of mixtures of two or more stocks. Wellington and his successor, Hatton, separated the various stocks, designated them by numbers and applied the proper names so far as they could be ascertained. Hatton and his co-workers at East Malling have, during the past 25 years, given much study to these stocks and their interrelations with English varieties of apples. Several American Experiment Stations and the United States Department of Agriculture have imported these stocks. The Massachusetts Station secured 16 of them in 1926 and has since added others and propagated them by layers, nurse-root grafts, and root cuttings and used them as rootstocks on which to bud our varieties.

These rootstocks are known in this country by their Malling numbers rather than by names. Some of them have proved to be dwarfing stocks, but others have little or no dwarfing effect. The numbers and names, so far as given, of the stocks in the nurseries of the Massachusetts Experiment Station are as follows:

Very dwarfing stocks: Malling VIII — French Paradise
" IX — Yellow Metz

Semi-dwarfing stocks: Malling I — Broad leaved Paradise
" II — True Doucin
" III — "Hollyleaf"
" IV — Holstein Doucin, Yellow Doucin
" V — Improved Doucin
" VI — Nonesuch Paradise
" VII — Not named

Near standard or standard stocks: Malling X — Not named
" XII — Not named
" XIII — Black Doucin
" XV — Not named
" XVI — Ketziner Ideal

The classification into very dwarfing, semi-dwarfing, and standard rootstocks is to be taken only in a general way. The stock effect varies with the variety. A given stock may produce small trees of some varieties and larger trees of other varieties.

Certain other rootstocks have been used to a limited extent. Malling A, C. F, and H are unnamed seedling selections. They are, with the exception of H, all vigorous growing stocks and do not always root well in the stock bed. Trees budded on these stocks have shown no distinct dwarfing effect. Malling H is a very wayward growing, thorny stock that seems to show no valuable qualities.

Two rootstocks sent out by the U. S. D. A. have been tried to a limited extent. One known as Spy 227 is derived from a seedling of Northern Spy and is resistant to the woolly aphis, a quality of little importance in northern orchards where the woolly aphis does little damage. This rootstock does not seem to be adapted to a wide range of varieties. It is reported to have considerable dwarfing effect. Another stock known as Vt. 323 is a vigorous stock inclined to produce many short thorny growths from the stem. It seems to be of value when large vigorous orchard trees are desired, but should not be used for growing semi-dwarf trees. None of these rootstocks seem likely to come into general use in this region.

It is not proved that the Malling rootstocks are truly clons; that is, that each is derived from one seedling tree; therefore, they are called types rather than clons. All trees of a given type are alike insofar as the writer has been able determine. This being so, it is remarkable if more than one seedling is represented in a given type when it is pure and unmixed. Among the hundreds of cultivated varieties originating from seedlings and propagated in nurseries, all of which are true clons, it is doubtful if there are any that cannot be recognized and distinguished from all others in the nursery row. The writer is convinced that the Malling types are true clons.

Formerly, both seedling and clonal rootstocks were largely imported from Europe by American nurserymen, but since 1928 importation has been forbidden on account of the danger of importing plant pests. Previous to this quarantine order, many seedling stocks were grown, mostly in Kansas and in the Pacific northwest, and sold to nurserymen in all parts of the country. These stock growers have continued to supply nurserymen with seedling rootstocks since importations were forbidden, and some have attempted to produce clonal stocks by various methods. At the present time, owing to the increased demand for dwarf and semi-dwarf trees, there is increased interest in growing clonal rootstocks. It is more difficult and a little more expensive to grow clonal rootstocks than seedling rootstocks, but the present high price of dwarf trees is due to the relation between supply and demand more than to the increased cost of growing trees on the dwarfing rootstocks.

The clonal rootstocks now being grown in this country have come in part from the importations by the U.S.D.A. and experiment stations previously referred to and in part from prequarantine importations by nurserymen. The writer has seen many stocks descended from these earlier importations. All have been Malling II, III, or V, or often a mixture of two or all three of these. We had some stocks many years ago under the name of French Paradise which were probably Malling VIII, but we have seen none in recent years. This corresponds to the situation found by Hatton. Evidently the early importations of dwarf apple stocks were mixtures of different types, which may account in part for the poor results from dwarf trees reported by early American investigators.

Propagating Clonal Rootstocks

As clonal rootstocks cannot be reproduced from seeds, it is necessary to resort to asexual methods of propagation. We might expect that the convenient means would be by cuttings. Most of them grow quite readily from root cuttings and some grow sparingly from stem cuttings. No method of handling stem cuttings so as to get a stand sufficient to make the method practical is known to the writer. Material for root cuttings is not often available in quantity. When one digs nursery trees propagated on a known clonal rootstock, he may be able to recover roots for a considerable number of cuttings. The value of a nursery tree depends more on the number of roots than on their length; consequently long roots may be shortened and the pieces used as root cuttings. The roots must be not over two years old and should be 3/16 inch or more in diameter and 3 to 5 inches long. The cuttings are lined out in nursery rows in a slanting position with the top end of the root at the surface of the soil. Under good growing conditions, they may be large enough to bud the first summer or they may be held over until the second season and then budded.

Clonal rootstocks may also be reproduced by nurse-root grafts. Scions of one-year wood from the desired clon are whip grafted on short, straight seedling roots and planted like ordinary root grafts. The top of the scion should be at the surface of the ground. When the new growth is 4-6 inches tall, moist soil is hilled up around it to favor rooting. Most clonal rootstocks thus handled will produce roots in practically every case the first season. When the grafts are dug in the fall or spring following planting, the seedling root piece is cut off and the rooted scion lined-out for budding.

These methods of propagation are rather slow and cumbersome. The usual and best way to produce clonal rootstocks is by stooling or by layering. A stool or layer bed should be established only on strong soils. A fertile sandy loam is perhaps best, but doubtless a considerable range of soils may be found suitable. The soil must be well drained so that there will be no heaving of the roots from winter freezing nor a high water table during the growing season; yet it must not have excessive drainage so that the plants suffer during dry periods. If well-rotted stable manure is available, a heavy coating may be plowed in before the plants are set unless the soil is already in a high state of fertility. Either too low or too high fertility is undesirable. Incorporation of peat moss or similar organic matter improves the physical condition, especially of heavy soils, and favors cultural operations as well as the growth of the plants.

The Malling apple rootstocks may be reproduced satisfactorily by stooling, also called mound layering. Vigorous well-rooted plants should be used. If the plants are not very vigorous and well rooted, they may be lined-out and grown for a year or two before setting in the stool bed. It is well to have a supply of such plants on hand to replace plants that fail in the permanent bed.

The plants are set about 18 inches apart in furrows 5 to 6 feet apart. They are set in furrows to keep the crowns of the plants low and the rather wide space between the rows is to make plenty of soil available for hilling up the shoots as described later. Much depends on a vigorous growth the first year as it is necessary to have a root system at least equal to that of a one-year tree if a good yield of rooted plants is to be obtained. On the other hand, growth may be too vigorous, and excessively vigorous shoots do not root as well as do those of moderate vigor. Plants may be set in the fall, if available, provided that severe winter weather is not probable. Spring setting is satisfactory, but it should be done as early as one can manipulate the soil. Care during the summer should be the same as with other nursery stock.

In the spring of the second year, the shoots are cut near the base, care being taken not to damage the shoots. A few to several shoots will start from the crown of the plant. As soon as the new shoots are about 4-6 inches tall, moist earth is hilled up around the bases covering the basal half of the shoots. It is important to start hilling up while the bark is soft and green. This is repeated about twice as the shoots grow until there is a layer of 4-6 inches of moist soil around the bases of the shoots. The soil must be placed by hand, care being taken to spread the shoots to make a rather wide row. A plow or celery hiller may be used to throw up a ridge close to the row of plants and the mound completed by filling in between the shoots.

The production of shoots and the proportion of them developing roots varies with soil, rootstock, and season. In most years nearly all the medium-sized shoots form roots. A transplanted shoot having very few roots will often live, but the more roots it has the better it will grow.

If a newly set stool bed does not show vigorous growth following setting, it may be advisable to allow the plants to grow for a second season before hilling up. In such cases, the sacrifice of one year's crop will be amply returned by better crops in later years. Too much vigor is also to be avoided as very vigorous shoots do not root as well as those of moderate vigor.

The rooted shoots may be removed in late fall, but our experience is that it is better to wait until early spring. As soon as frost is out of the ground the mound is leveled off and the well-rooted shoots cut off as low as possible. Very weak shoots may be left for another year until they become well-rooted plants. Strong shoots not rooted should be removed or else laid down as discussed later. After removal of the shoots the bed is kept well cultivated until new shoots start from the crowns when the hilling process is repeated. Most shoots come from dormant or adventitious buds in the stem tissue but some rootstocks will produce new shoots from the roots. Effort must be made to keep the crowns as low as possible or they will get so high as to make hilling difficult.

A stool bed once well established will last for many years, yielding a crop of rooted shoots each year. If the plants lose vigor, a coating of well-rotted manure or a commercial fertilizer may be expected to invigorate them; but a good start in the early years and good physical condition of the soil are more important.

A somewhat different method of growing clonal rootstocks is called layering. This differs from stooling in that the plants are set a little farther apart in the row and in a slanting position. Instead of cutting off the shoot the next spring, the shoot is pegged down in a horizontal position. Any long branches are tipped back and the little tree covered with an inch or so of soil. The buds break and push up through the thin layer of soil. They are then mounded as in stooling. This method is used with rootstocks that do not root very freely and may sometimes be used in stool beds to fill vacant places where plants have failed, though it is probably better to fill in with new plants from lined-out stock. The laid down shoots may produce new shoots for a second or third year, but they soon fail and new strong shoots must be laid down from year to year.

Yields vary greatly with soil, stock, and season. Malling IV, VII, XIII, and XVI seem to be the most productive types. The others are less productive or seem to be variable. More experience is necessary before we can feel sure of the productive capacity of the different types.

Good stock beds will usually yield from 15,000 to 30,000 rooted layers per acre per year. Higher yields are possible with productive rootstocks and lower yields are by no means rare. The severe cutting necessary is hard on the plants and some, failing to make new shoots, may die. Vacant spaces may be filled in by setting new plants or laying down vigorous shoots. Plants that have been lined out for a year or two are preferable for replacements.

Plants from stool beds are lined out in the nursery row, managed, and budded like seedlings. They are not often grafted. Most varieties grow as well on clonal roots as they do on seedling roots, though on the very dwarfing clonal stocks they are sometimes a little stockier and have shorter internodes. The dwarfing effect does not become striking until the trees begin to bear.

In budding seedlings, one finds that the bark of some individuals does not slip well and it is difficult to insert the bud; failure of the bud is more frequent in such cases. Clonal stocks are more uniform in this respect. Some of the more dwarfing stocks mature earlier than do the vigorous stocks and budding these must not be delayed.

If trees budded on clonal rootstocks are planted in the orchard so that the base of the growth from the bud is surrounded by moist soil, the scion will send out roots. If a dwarfing stock has been used, these scion roots will prevail, and sooner or later the tree will be on its own roots instead of on the dwarfing roots. Thus the stock effect is lost. It follows that trees on clonal stocks should be budded higher than is the usual practice of nurserymen. It is desirable to bud trees on clonal stocks 4 to 6 inches above the ground and plant them in the orchard so that the union between scion and stock can be plainly seen. It has been shown that high budded trees grow as well as low budded trees, or better. A possible objection to high budding is that more of the rootstock may be exposed to winter injury, but scion rooting is a greater evil. In orchard operations, great care is taken never to allow the soil to be heaped around the base so as to give opportunity for the scion to send out roots.

CLONAL STOCKS IN THE ORCHARD

The performance of our many varieties on the various clonal rootstocks presents a complicated problem. Not enough is yet known to warrant complete and accurate statements; consequently, only a few generalizations will be attempted here. There are very few, if any, varieties that will fail to grow and bear fruit when budded on any of the Malling rootstocks. However, not all combinations are equally satisfactory. Conversely, a given rootstock controls different varieties in different degrees. Malling IX, for example, does not dwarf all varieties to the same extent. Soil and other environmental conditions often control the growth and fruiting more than the rootstock. Therefore, environmental influences are most important and may account for many of the apparently contradictory reports on various stock-scion combinations. The fruit of trees on dwarf rootstocks is like that of the same varieties on seedling stocks; often it is better colored and larger on young trees. With increasing age, the apples tend to be small unless the vigor of the tree is maintained and the fruit properly thinned. This leads to the suggestion that dwarf trees do not endure unfavorable conditions as well as those on the usual seedling roots.

Cultural management and pruning should be much the same as for standard trees except that dwarf trees may require somewhat higher fertility. They reach maturity earlier because they are less vigorous and bear heavily. In the early bearing years they produce more per tree, but in later years, standard trees bear more because the trees are larger. More trees per acre are set and acre yields may be expected to equal or exceed those of standard trees. More trees per acre means greater planting expense, but the cost of trees is a minor item in the total cost of establishing an orchard. The present price of dwarf trees is very high, but prices may be expected to be more in line with those of standard trees when the necessary rootstocks are more plentiful. The actual cost of growing dwarfing stocks and trees should not exceed that for standard trees by more than 10 percent.

Hardiness

The hardiness to cold of Malling stocks is of importance. In general, they are as hardy as French Crab seedling stocks; some are distinctly more hardy. In the colder apple sections, French Crab seedling stocks sometimes are winter-killed, and for such regions the Malling stocks are of doubtful value. Trees on seedling stocks are planted with little or none of the stock exposed to air temperatures, and soil temperatures rarely fall low enough to kill apple roots of any kind except in regions of exceptionally severe cold. Dwarf trees must not be planted so deeply; hence, the stock tissues just below the union will be exposed to low air temperatures. No winterkilling of trees on the Malling stocks in Massachusetts has been reported up to the present time.

Anchorage

One possible weakness of dwarfing rootstocks is poor anchorage. Trees on these stocks may blow over when exposed to severe winds, especially if they are carrying a heavy load of apples. The different rootstocks vary; some are better anchored than others. Trees on semi-dwarf stocks stood the hurricane of 1938 nearly if not quite as well as standard-sized trees. Yet future experience is needed to show whether poor anchorage is a real weakness of such trees. Very dwarf trees are often poorly anchored and need support.

Very Dwarfing Stocks

The very dwarfing stocks, Malling VIII and IX, meet little approval from commercial growers. Trees on these stocks are expected to grow not over 8 feet high at maturity and to begin to bear after 2 to 5 years in the orchard depending on the variety, soil, and culture. Varieties like Golden Delicious, which bear at an early age when grown on seedling stocks, should bear after 2 or 3 years in the orchard while Baldwin and Northern Spy require 2 or 3 years more. Fruiting is much influenced by cultural management. Trees can be planted from 8 to 12 feet apart and are, therefore, well suited to the backyard where space is limited.

Malling IX is a better stock for the nurseryman than Malling VIII and may be as good or better in an orchard or backyard. For these reasons trees on Malling IX are, and are likely to continue to be, more often available to the buyer. Trees on this stock have their faults. Their anchorage is poor and the wood is brittle; consequently, they are apt to blow over or break at or below the union. They should be headed low and grown more as bushes than as trees. The danger of breakage can be overcome by staking the trees. Mice and rabbits seem to prefer these stocks; at any rate, it is wise to protect the trees by the usual means.

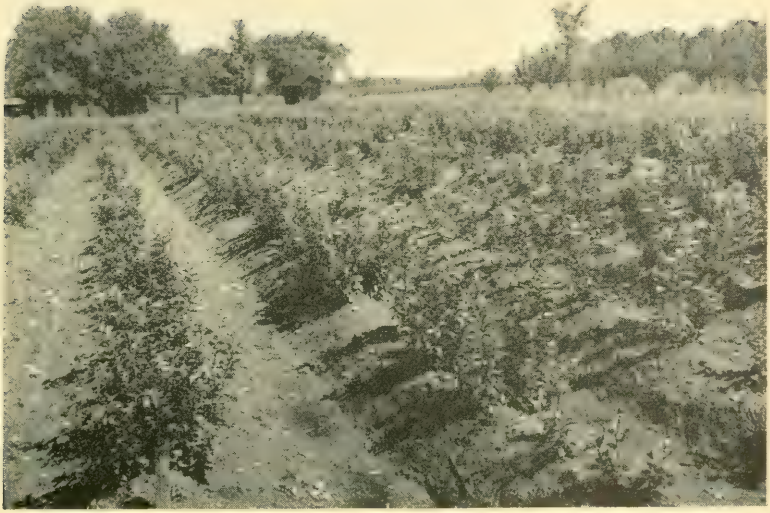
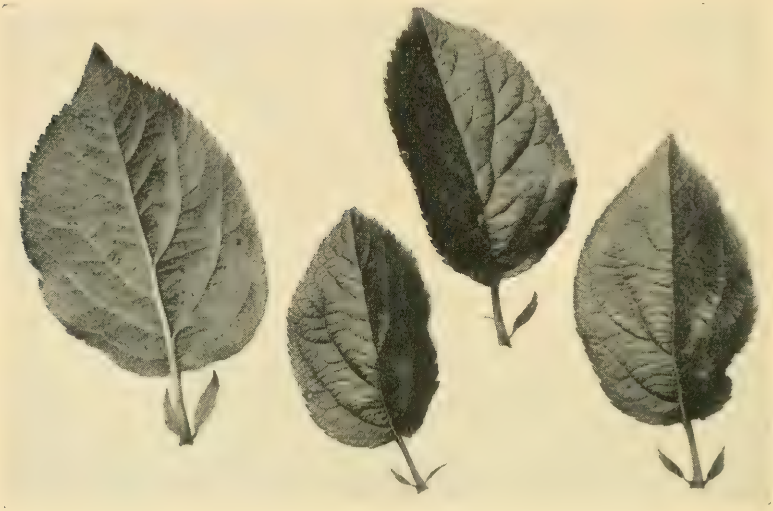


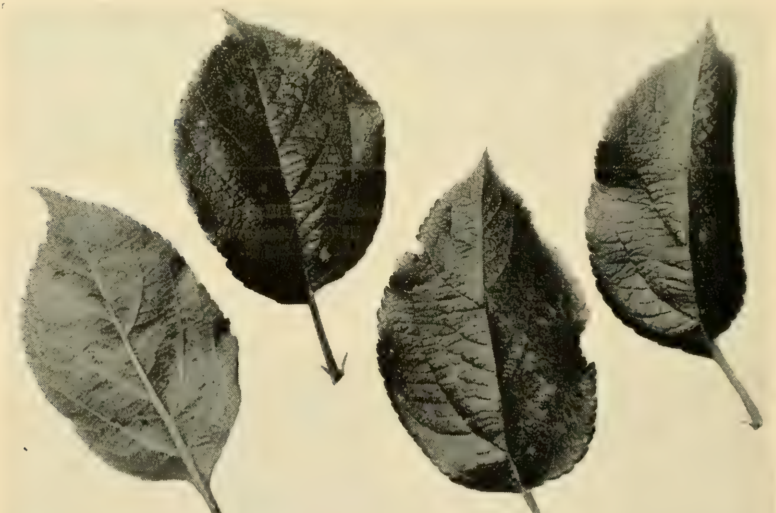
Figure 1. Clonal Rootstock Bed, Hilled up.
Left to right: Malling V (beyond stake); Malling VIII (two plants) and Malling III (same row, beyond stake); Malling I; Malling II.



Malling I.

Leaf rather large and broad, somewhat folded and waved, with rather sharp serrations; petiole stout, usually with large stipules.

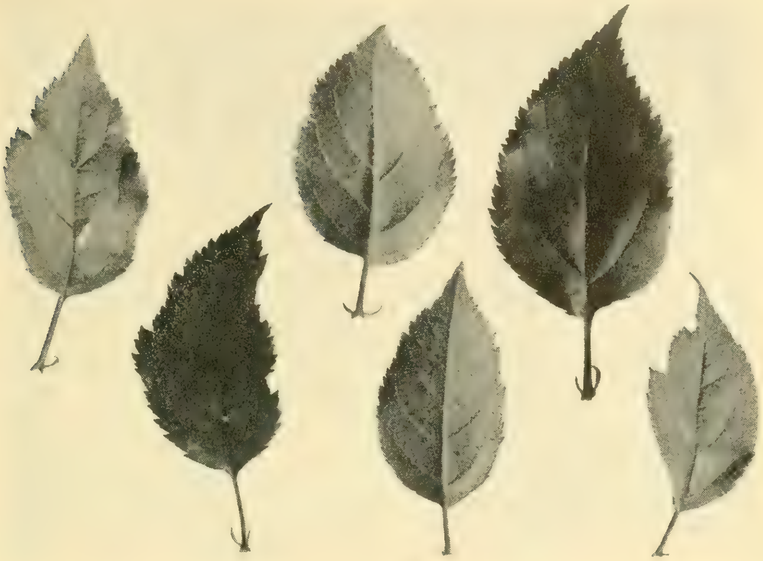
Growth rather tall and stout. Bark dark with moderately conspicuous lenticels.



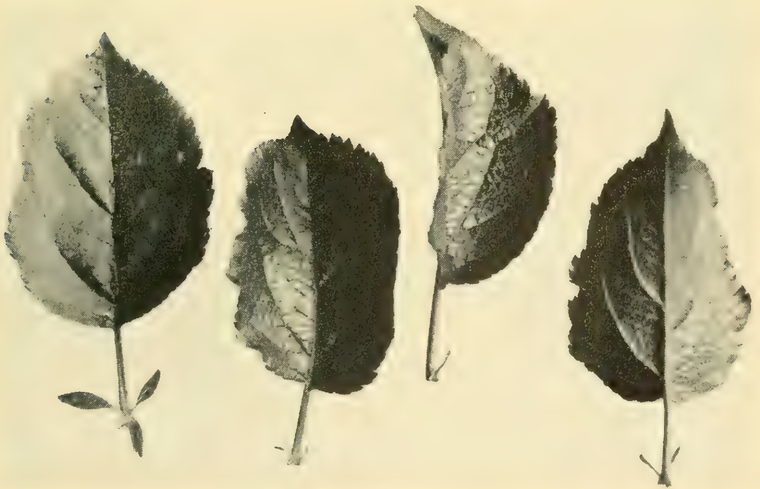
Malling II.

Leaf medium sized, with rather dull, shallow serrations, short distinct tip, slender petiole, and small or no stipules.

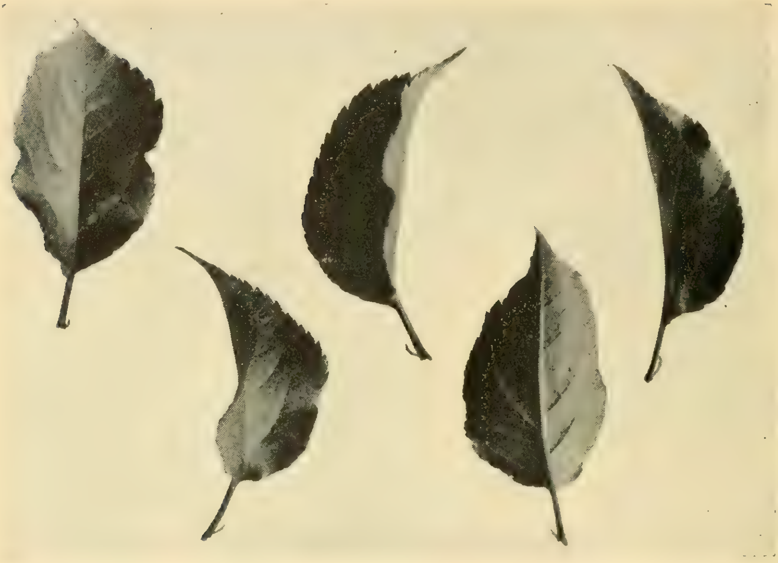
Growth stout. Bark with whitish, conspicuous lenticels.



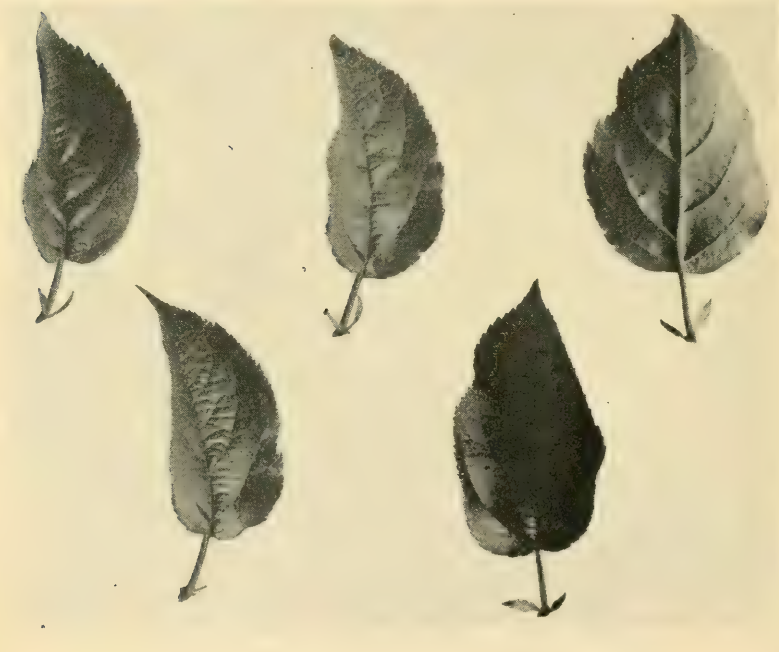
Malling III.
Leaf small, sharply pointed, with sharp, distinct serrations.
Growth slender. Bark dark with inconspicuous lenticels.



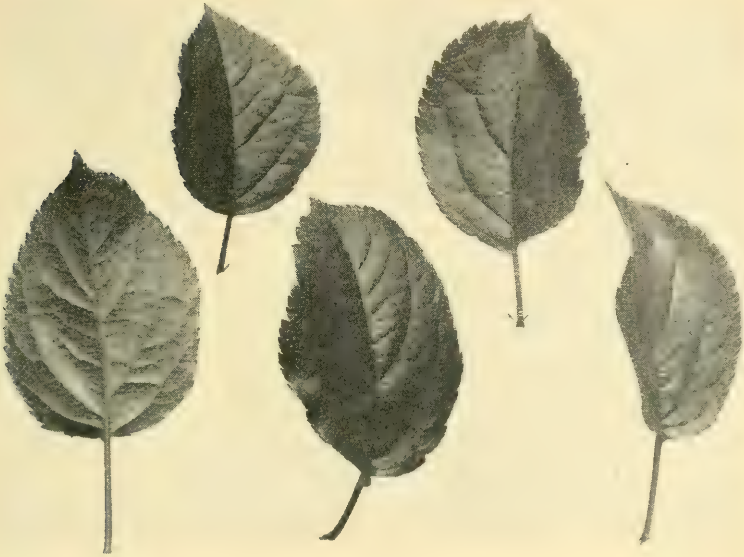
Malling IV.
Leaf roundish with short distinct tip and irregular, rather dull serrations.
Growth rather short and somewhat slender. Bark yellowish, with few brownish inconspicuous lenticels.



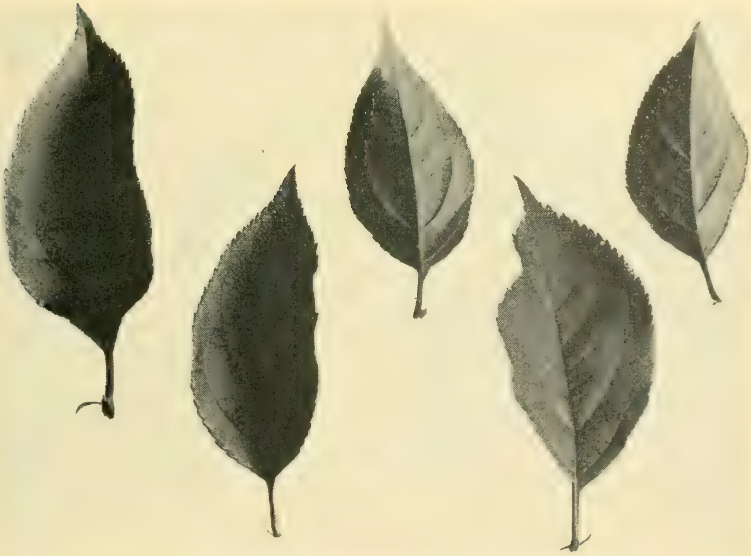
Malling V.
Leaf generally small, often with a cup-shaped folding, with a distinct point. Growth medium. Bark dark with inconspicuous lenticels.



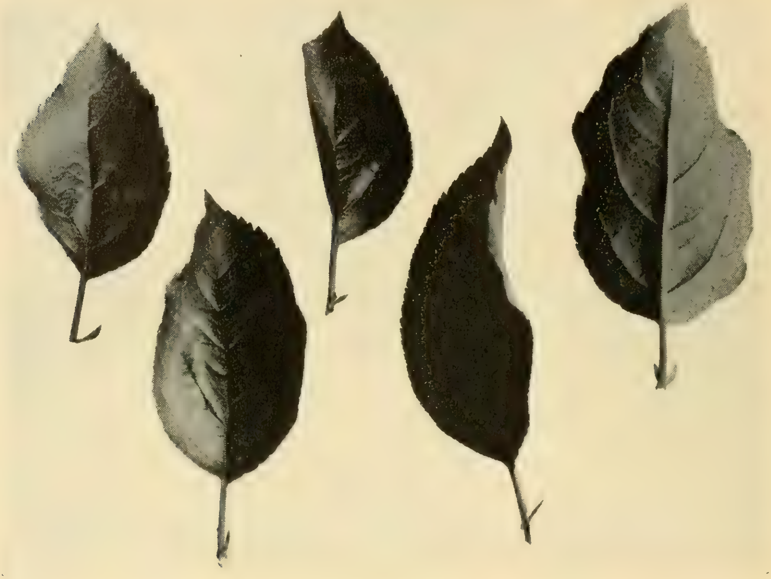
Malling VI.
Leaf medium sized, pointed, with medium sharp serrations, short petiole, and usually stipules of medium size.
Growth quite tall and vigorous. Bark yellowish with rather inconspicuous brownish lenticels.



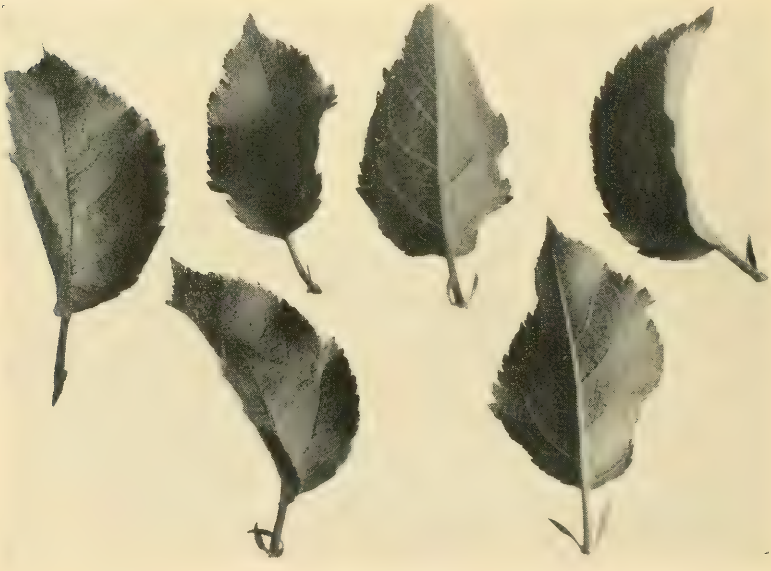
Malling VII.
Leaf medium sized, roundish, pointed, with rather sharp serrations.
Growth rather slender. Bark dark with moderately conspicuous lenticels.



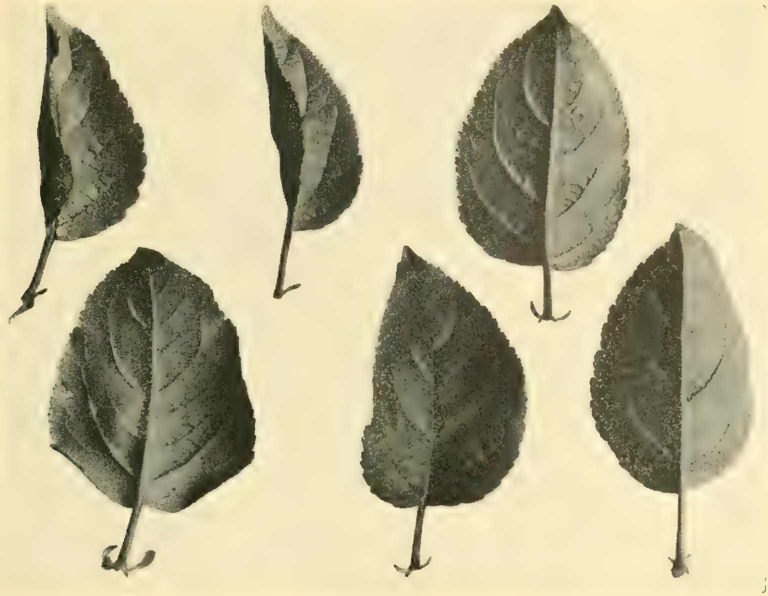
Malling VIII.
Leaf rather large with long tip, narrow base, and dull, shallow, regular serrations.
Growth spreading, stout. Bark reddish with conspicuous lenticels.



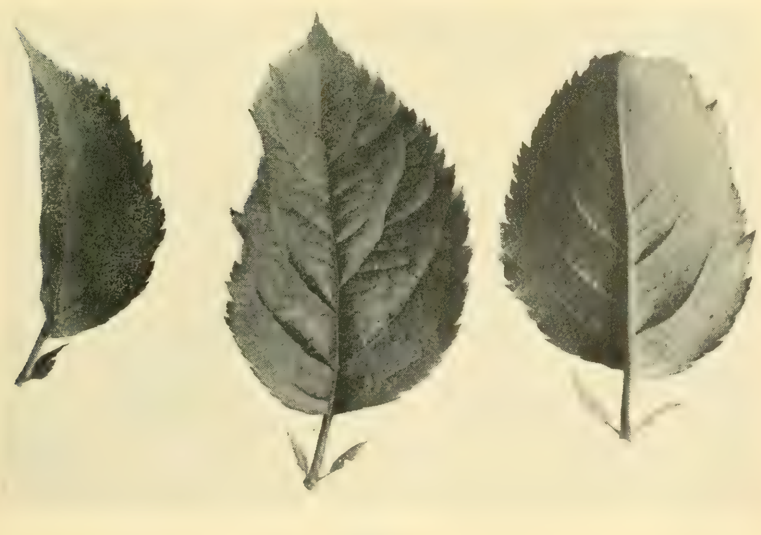
Malling IX.
Leaf rather large, little folded and waved, with somewhat dull serrations, quite glossy. Growth rather spreading. Bark slightly reddish with rather few, inconspicuous lenticels.



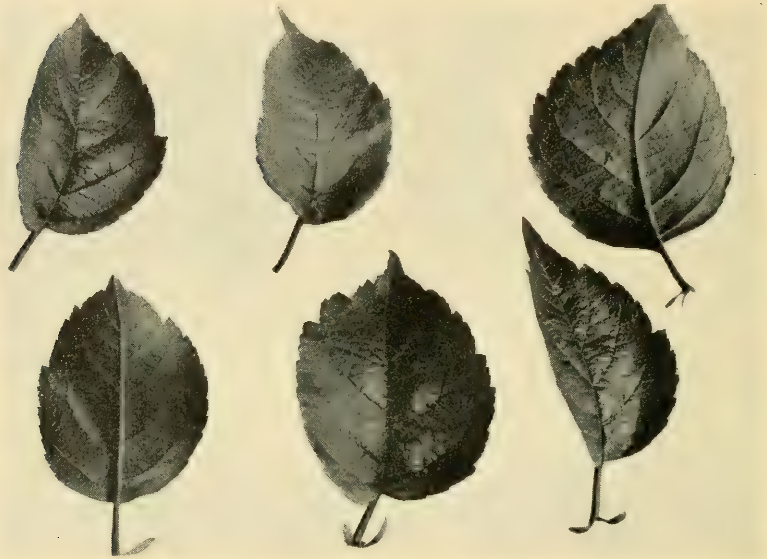
Malling X.
Leaf oval, more or less folded and waved, with sharp, distinct serrations. Growth moderately tall. Bark with many rather distinct lenticels.



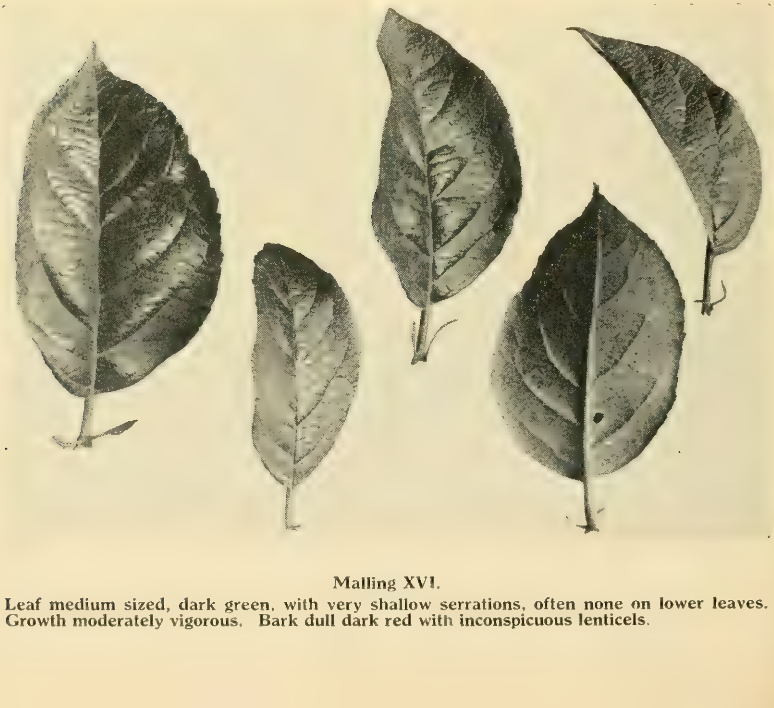
Malling XII.
Leaf oval to ovate, without tip and with dull, shallow, regular serrations.
Growth tall, upright. Bark reddish brown with not very conspicuous brownish lenticels.



Malling XIII.
Leaf large, pointed, with rather sharp, irregular serrations.
Growth tall, rather stout. Bark with moderately conspicuous lenticels



Malling XV.
Leaf medium sized, broad, oval, flat, with moderately sharp, shallow serrations. Growth rather tall and stout. Bark with few grayish inconspicuous lenticels.



Malling XVI.
Leaf medium sized, dark green, with very shallow serrations, often none on lower leaves. Growth moderately vigorous. Bark dull dark red with inconspicuous lenticels.

Semi-Dwarfing Rootstocks

The semi-dwarfing Malling rootstocks are not alike in their dwarfing influence, but there is not very good agreement on the dwarfing effect of the several stocks. Trees on these stocks may be expected to grow from one-half to two-thirds the size of standard trees of the same variety. They will rarely exceed 15 to 20 feet in height at maturity and do not require as wide spacing. For these reasons, they have attracted the attention of fruit growers who dislike tall trees. They should be planted from 20 to 35 feet apart according to variety and soil. They may be planted and handled in exactly the same way as standard trees except that the union must be above ground and they may require a little higher fertility. They are suitable for fillers when one desires to plant an orchard on this system. Thus, an entire row may be planted with one variety, which simplifies orchard management.

There are 7 semi-dwarfing rootstocks, and it seems wise to introduce only the best ones. Malling III sprouts from the stock more freely than the others and this habit is a nuisance. It is hardy and reproduces well in the stock bed. Malling VI does not reproduce very well and seems to have no superiority in other respects. The other semi-dwarfing rootstocks are all good. Doubtless further experience will show that some are not as satisfactory as others at least for some varieties. We are inclined to favor I, II, IV, and VII as the semi-dwarfing stocks most likely to prove valuable and it would simplify matters if this list could be shortened. A large number of rootstocks complicates matters and increases the chances of mixtures.

Standard and Near Standard Rootstocks

The standard and near standard Malling rootstocks, numbered from X to XVI, produce trees that are much like trees on seedling rootstocks. It is yet a question whether such trees are superior to seedling rooted trees. As has been said, little is to be hoped for in greater uniformity or in eliminating poor trees in the orchard. We do not have Malling XI and XIV, and they have not excited any interest in this country. Malling XIII seems to be capricious as to soils and some varieties do not succeed well on it, while X and XV seem to have no outstanding qualities. This leaves XII and XVI as the more desirable clonal rootstocks for full-sized trees. Malling XII is a good stock for all varieties and seems well suited to most of the ornamental crabs, many of which fail on the dwarfing stocks. Malling XVI reproduces well, although it often does not produce a good root system in the stock bed. It grows and buds well in the nursery and produces satisfactory, large, productive trees for the orchard. We consider it the most desirable of the vigorous Malling stocks.

DESCRIPTION AND IDENTIFICATION OF CLONAL ROOTSTOCKS

With the increasing use of clonal stocks, the problem of keeping the different types pure and true to name becomes more and more important. There seems to be some tendency to regard all clonal stocks as dwarfing; this is not true. With a wider knowledge of the interrelations of stock and scion, the importance of using the proper stocks for various varieties will be greater. Nurserymen and others growing trees on clonal stocks must know what stock they are using and inform their customers. They must, therefore, avoid mixing stocks in the nursery row.

While the different clonal rootstocks can be identified before they are budded, it is difficult and often impossible to tell what stock is under a budded tree either in the nursery or in the orchard. The growth of the tree may give some indication but is likely to raise more questions than it settles. In some cases, sprouts from the rootstock may prove its identity, but sometimes they make poor growth in the shade of the tree. In most cases, no sprouts appear. With the exception of Malling III, none of the Malling stocks sprout from the stock more frequently than do seedling-rooted trees. It is small satisfaction to discover that one has the wrong rootstock after the trees are planted in the orchard. Stock beds and lined-out stocks should be examined and rogued of mixtures. It has been our experience that stray trees sometimes appear in the stock bed and nursery rows and their source is sometimes a mystery.

All the clonal stocks we have grown can be identified as well as can our cultivated varieties, but it requires careful observation and considerable study to do so. They can be identified in the stock bed or in the nursery row before the tops are cut following budding. It is best to look at them while in leaf though some can be named quite positively when dormant. They must make at least moderately vigorous growth; weak trees do not show varietal characteristics clearly and are always a problem. While it is best to examine lined-out stocks late in the summer just before budding, it can be done after budding but before the leaves fall. However, the discovery of a mixture after the trees have been budded, brings out a situation that is difficult to correct.

Before attempting to describe certain clonal rootstocks, it is necessary to point out the characters of the plant that are useful in identification and attempt to define the terms used. In the descriptions the characters are treated in the same order as they are here given,

Growth

Vigor and type of growth vary with growing conditions. Descriptions must, therefore, be comparative. Some stocks are taller and of larger diameter than others. For instance, Malling I is always taller than Malling IV and stouter than Malling III when all are growing under similar conditions. Some, as Malling XII, are very upright while Malling VIII makes a spreading or sprawling growth. The growing tips of some stocks are more or less tinged with red, while others are green or yellowish green.

Internodes

The internode or the distance between the leaves on the current season's growth is generally shorter than in our cultivated varieties, especially with the more dwarfing stocks. This gives the shoot a more leafy appearance.

Spurriness

The clonal stocks show many short stiff growths that do not grow into normal branches. Their presence is objectionable because they interfere with easy budding. While they have value for identification purposes, their number varies greatly with season and cultural conditions; yet their relative abundance on different rootstocks in one stockbed will be fairly constant.

Bark Color

The bark color is distinctive but very difficult to describe. It varies with age and growing conditions. Young bark is green, but it soon darkens to some shade of olive, brown, or red, or a blend of these colors. The bark color usually described is that typical of midsummer or late summer after the most vigorous growth is over and the bark is partially matured.

Lenticels

The lenticels or light colored dots on the bark are very distinctive. They vary in number, size, shape, and color. Some are flush, that is, even with the surface of the bark. Others are more or less distinctly raised and can be felt with the thumb or finger. This character also can be seen with a small magnifying glass. Those that appear in large numbers, are of large size, and are light colored are the more conspicuous.

Leaf Blade

Some stocks have larger leaves than others though there is great variation on a single plant. The observer should consider the normal well-developed leaves located usually about in the middle of the shoot. They usually vary from oval to ovate, but some stocks have leaves that are nearly round. Some have a distinct or rather long tip, while others have a very short tip or none at all. Most leaves are more or less folded upward; sometimes the folding is near the edge, while in others it begins near the midrib. Some stocks have leaves that are a little folded downward. The leaf edge may or may not be waved, either finely or coarsely. Rugoseness refers to the rough uneven surface of the leaf, while a bullate leaf shows the net veining of the leaf quite distinctly. Glossiness refers to the light reflection from the leaf surface. Young leaves near the growing tip are more glossy than the other leaves below. One must compare leaves that are of the same age. It is necessary to have a good light to do this. Differences are not always easily seen, but when one learns to observe carefully in a good light, it is of great help in identifying certain stocks.

Leaf Base and Tip

There are differences in the shape of the base of the leaf blade that are of value in identifying rootstocks. The base is generally rounded but some are broad while others have a tendency to narrowness. Some stocks show a tendency towards a cordate or heart-shaped base. Usually the two sides meet the petiole exactly opposite each other, but in some stocks there is a tendency for one side to be lower than the other and these are described as uneven.

Serrations

The serrations along the leaf edge are very characteristic of the different stocks; they vary in size, sharpness, and depth. On some leaves there is little space between the serrations; while on others the serrations are well spaced and are said to be distinct. Some rootstock leaves have serrations all very much alike; others vary in size and depth; they are said to be regular or irregular, as the case may be.

Petiole

The petioles or leaf stems vary in the angle which they form with the stem, in length, and in thickness, and the differences though small are quite constant. There seems to be little value for identification purposes in the furrow that is always seen on the upper surface of the petiole.

Stipules

The stipules are two small leaf-like structures at the base of the petiole. They vary somewhat in size and in some stocks there is a tendency for the stipules to grow much larger than normal so that they resemble small leaves. The stipules often drop off during the summer. Their persistency varies with conditions of growth.

DESCRIPTIONS OF MALLING CLONAL STOCKS

A beginner cannot expect to make very great progress in naming an unknown clonal rootstock by reading the following descriptions. The differences are rather small and it is difficult to select easily understood phrases to describe the various rootstocks. Anyone attempting a serious study of them should find these descriptions helpful in seeing the identifying characters. He should start by comparing these descriptions with plants known to be true to name or number. Thus, he may learn what the writer means by the various phrases. It is not very difficult to learn to know these rootstocks if one is willing to observe closely and work hard at the problem.

Malling I

Growth: medium to tall, rather stout, growing tips slightly tinged.*

Internodes: medium in length. **Spurs:** none to few.

Bark: medium brownish olive.

Lenticels: medium in size and number, round, brownish gray, slightly raised, moderately conspicuous.

Leaf Blade: medium to large, broad oval to ovate, more or less folded, somewhat coarsely waved, rather rugose, bullate, slightly glossy. **Base:** round to slightly cordate, wide, even. **Serrations:** quite sharp, moderately deep, quite distinct.

Petiole: spreading or slightly upright, short, moderately thick.

Stipules: large.

Malling II

Growth: short to medium, rather stout, growing tips greenish or very slightly tinged.

Internodes: short. **Spurs:** medium to many.

Bark: greenish to brownish olive.

Lenticels: medium in number, large, round, whitish, slightly raised, conspicuous.

Leaf Blade: medium sized, oval, moderately folded, nearly even, rather smooth, dull, somewhat glossy at tip of shoots. **Base:** round, even, narrow. **Serrations:** dull, fine, shallow, regular, not distinct.

Petiole: spreading to slightly upright, short, medium to thick.

Stipules: small.

Malling III

Growth: moderately tall, rather slender, growing tips greenish or slightly tinged.

Internodes: short to medium. **Spurs:** few to medium.

Bark: dull dark reddish, lighter towards base.

Lenticels: few, small, round, brownish gray, flush, inconspicuous.

Leaf Blade: small, oval to ovate with a long distinct tip, flat or sometimes down folded, often reflexed. **Base:** round, narrow, even. **Serrations:** sharp, usually deep and distinct.

Petiole: upright, short to medium, slender.

Stipules: none or very small.

---

*In these descriptions, "tinged" means tinged with red.

Malling IV

Growth: short and rather slender, growing tips yellowish green or slightly tinged.

Internodes: very short. **Spurs:** medium.

Bark: greenish or yellowish olive.

Lenticels: few, small, roundish, brownish, flush, inconspicuous.

Leaf Blade: medium sized, roundish with small tip or none, moderately folded at edge, not reflexed, little waved, rather smooth, somewhat bullate. **Base:** round, wide, even. **Serrations:** moderately sharp, shallow, quite regular, not distinct.

Petiole: somewhat upright, short, slender.

Stipules: small.

Malling V

Growth: medium to rather tall, medium sized, growing tips green, not tinged.

Internodes: short to medium. **Spurs:** none to few.

Bark: dark reddish brown.

Lenticels: few, rather small, round or slightly elongated, whitish, flush, inconspicuous.

Leaf Blade: rather small, oval or slightly ovate with distinct short tip, more or less folded near edge, not reflexed, little waved, smooth, slightly bullate. **Base:** round, rather narrow, even. **Serrations:** rather dull, shallow, quite regular, not distinct.

Petiole: spreading, short, slender.

Stipules: none or very small.

Malling VI

Growth: medium to tall, medium sized, growing tips yellowish green, not tinged.

Internodes: short. **Spurs:** none.

Bark: yellowish olive.

Lenticels: medium in number, small, round, brownish gray, slightly raised, not very conspicuous.

Leaf Blade: medium sized, oval to ovate with moderately distinct tips, more or less folded, not reflexed, little waved, rugose. **Base:** round to cordate, wide, even. **Serrations:** medium in sharpness and depth, irregular, moderately distinct.

Petiole: spreading, short to medium, thick.

Stipules: medium to large.

Malling VII

Growth: medium in height, rather slender, growing tips greenish or very slightly tinged.

Internodes: short to medium. **Spurs:** none to few.

Bark: dark reddish brown, lighter at base.

Lenticels: medium in number, small to medium, roundish, medium gray, raised, moderately conspicuous.

Leaf Blade: medium sized, broad oval, often with a short distinct tip, flat, sometimes down folded at edge, not waved, smooth, somewhat bullate, principal veins often reddish. **Base:** round, broad, even. **Serrations:** sharp, shallow, somewhat irregular, not very distinct.

Petiole: spreading, short to medium, slender.

Stipules: none or small.

Malling VIII

Growth: short to medium, stout, spreading or sprawling, growing tips yellowish green, not tinged.

Internodes: short to medium. **Spurs:** none to few.

Bark: dark reddish extending to the base.

Lenticels: many small to medium, roundish, light gray, flush, conspicuous.

Leaf Blade: medium to rather large, oval to ovate, narrowing to a medium to long tip, rather stiff, nearly flat, not waved nor reflexed, smooth. **Base:** round, quite narrow, even. **Serrations:** dull, sharper on basal leaves, shallow, very regular, not distinct.

Petiole: spreading, medium in length, slender.

Stipules: none or small.

Malling IX

Growth: short to medium, rather stout, somewhat spreading, growing tips moderately tinged.

Internodes: short. **Spurs:** few.

Bark: slightly reddish olive.

Lenticels: few, medium sized, round, gray, flush, inconspicuous.

Leaf Blade: medium to large, broad oval, little folded, little waved, somewhat rugose, glossy. **Base:** round, wide, even. **Serrations:** only moderately sharp, shallow, moderately distinct.

Petiole: spreading, short to medium, rather thick.

Stipules: none or few, of medium size.

Malling X

Growth: moderately tall, moderately stout, growing tips not tinged.

Internodes: short to medium. **Spurs:** few.

Bark: dark reddish brown.

Lenticels: many, medium to large, round, whitish, slightly raised, rather conspicuous.

Leaf Blade: medium sized, oval, more or less folded, often reflexed, distinctly and finely waved, not rugose, somewhat bullate. **Base:** round, of medium width, even. **Serrations:** sharp, moderately deep, irregular, distinct.

Petiole: spreading, short to medium, of medium thickness.

Stipules: small.

Malling XII

Growth: rather tall, moderately stout, upright, growing tips yellowish green.

Internodes: short to medium. **Spurs:** few.

Bark: reddish brown.

Lenticels: medium in number and size, round or sometimes elongated, brownish, flush, not very conspicuous.

Leaf Blade: medium sized, oval to ovate without distinct tip, moderately folded, slightly rugose, bullate. **Base:** round, wide, even. **Serrations:** dull, shallow, regular, not distinct.

Petiole: spreading, medium in length and thickness.

Stipules: small.

Malling XIII

Growth: tall, moderately stout, leafy, growing tips yellowish green.

Internodes: short. **Spurs:** medium to many.

Bark: dark reddish brown.

Lenticels: few to medium, large, roundish, brownish gray, slightly raised, moderately conspicuous.

Leaf Blade: large, oval, not folded, often reflexed, little waved, somewhat rugose, bullate, not glossy. **Base:** round, broad, even. **Serrations:** moderately sharp and deep, rather irregular, rather distinct.

Petiole: very upright, short, thick.

Stipules: large.

Malling XV

Growth: rather tall and stout, growing tips greenish.

Internodes: short. **Spurs:** few.

Bark: dull dark reddish.

Lenticels: few, small, roundish, gray, flush, inconspicuous.

Leaf Blade: medium sized, broad oval, flat to slightly folded, slightly reflexed, not waved, not rugose, bullate. **Base:** round, wide, even. **Serrations:** moderately sharp, shallow, somewhat irregular, not distinct.

Petiole: somewhat upright, short, of medium thickness.

Stipules: large.

Malling XVI

Growth: medium in height and stoutness, rather upright, growing tips green.

Internodes: short. **Spurs:** few.

Bark: dull dark reddish.

Lenticels: few, small, round, light gray, flush, inconspicuous.

Leaf Blade: medium sized, broad oval to ovate, flat to slightly folded, somewhat reflexed, sometimes a little down folded, dark bluish green. **Base:** round, rather narrow, often uneven. **Serrations:** moderately sharp, shallow, fine, quite regular, not distinct; many leaves with no serrations at all.

Petiole: moderately upright, short, medium thick.

Stipules: small to medium.

5791.41

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

FEB 15 1945

Bulletin No. 419 November 1944

Trellis Tomatoes

By Robert E. Young

The tomato is one of the most important vegetable crops in Massachusetts, and the details of its culture are of significant economic interest. This deals with the operation of a practice which has been growing in favor.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

IMPORTANT STEPS IN THE CULTURE OF TRELLIS TOMATOES

1. Make sure that the soil on the farm is sufficiently fertile to grow such an intensive crop.
2. Select a variety suited to the market and adapted to growing on trellis. Trellis No. 22, Waltham Forcing, and the variety Comet have done well in eastern Massachusetts.
3. Grow good plants. It is almost essential to have a greenhouse or plant house of some type. The use of pots, baskets, or plant bands is recommended; the added advantages are worth the additional cost.
4. Prepare the soil thoroughly. Proper plowing and disking are essential.
5. If manure is available, apply 10 to 12 cords per acre. This will maintain fertility and produce a more satisfactory crop.
6. Broadcast 1 ton of 5-8-7 fertilizer per acre. Use more on poor soil. Land low in fertility would benefit by the addition of ½ ton of superphosphate per acre.
7. In years of excessive rainfall, or on light types of soil, top-dress with nitrate of soda at the rate of 300 pounds per acre; or other nitrogen fertilizer to supply the equivalent amount of nitrogen.
8. Build a trellis strong enough to support a heavy crop.
9. Space the rows 4 feet apart. Set the plants 1 foot for single stem; 22 inches for 2 stems per plant. If ample land is available, use 2 stems per plant. If high yields per acre are desired, use 1 stem per plant.
10. Prune before side shoots are 6 inches long.
11. Keep the soil moist at all times.
12. Practice proper insect and disease control.
13. Harvest before the fruits are completely ripe. The proper maturity depends on the market and your marketing procedure.
14. Grade carefully and pack in baskets or ½-bushel boxes. An attractive package will sell at the highest price.

TRELLIS TOMATOES

Robert E. Young, Assistant Research Professor of Vegetable Gardening[1, 2]

Tomatoes are one of the most important market garden crops in Massachusetts. They are marketed almost entirely in local stores; very few are shipped or canned commercially.

During recent years there has been a change from the old method of culture in which the vines were allowed to grow untrained and unpruned. Under the new system the plants are supported on trellis or stakes, much as they are in the greenhouse. The only difference between the trellis and stake methods is the manner of supporting the plants. Some of the first growers of trellis tomatoes grew two rows in a hotbed, keeping the sash on until the plants were quite tall, and much of this fruit went to market as greenhouse tomatoes.

The shift from flat culture to trellis by the general market gardener started about 1930 and is still continuing. Because of the increased income, growers are willing to go to the expense and trouble of constructing a trellis on which to support their tomatoes. Fruit of better quality, greater early yield, and larger total yield result.

Trellising tomatoes increases the cost of production. More plants per acre are required; posts, wire, and string are necessary; and considerable labor is needed for pruning and training. These added costs are offset in part, at least, by (1) easier spraying of the plants to control insects and diseases, and (2) more efficient picking of the fruit since the degree of ripeness can be more accurately determined. Growers who have adopted the new system obtain fruit which stands up longer on the market — a matter of much importance in getting fruit of first quality to the consumer. With the new method of culture came a change to a small variety of fruit; and with the smaller, firmer tomatoes produced on the trellis, growers are in a better position to meet competition from other areas.

A number of factors must be considered when making the decision to grow the tomato crop on trellis. In many cases the most important are the facilities to be found on individual farms. Good soil and irrigation are necessary. Many growers have been reluctant to make the change because of a lack of information as to methods of culture which would produce the greatest returns per acre. The experimental work described in this bulletin was conducted to obtain practical information in this regard.

Comparison of Trellis and Flat Culture

Studies were conducted concurrently over a period of four years at Waltham and Amherst, Massachusetts, in order to compare the effect of different soils and climate on trellis tomatoes. Plots were replicated three times at each location. Waltham Forcing was the variety of tomato selected because it represented the type being grown on trellis, and the supply of seed was uniform and constant.

One part of this experiment was a comparison of flat-grown and trellis tomatoes, and the effect of trellising on the yield of fruit is shown in Table 1. Although the difference in total yield is not very great, it is in favor of the trellis method.

---

[1] Located at Waltham Field Station, Cedar Hill, Waltham, Mass.

[2] The writer gratefully acknowledges the assistance of Professor Alden P. Tuttle and William Lachman, Department of Vegetable Gardening, in conducting the experimental plots at Amherst.

TABLE 1. EFFECT OF TRELLISING ON THE YIELD OF TOMATOES.

Treatment	Yield per Acre, Pounds						Number of Fruits per Pound
	Waltham		Amherst		Combined Crop		
	Early	Total	Early	Total	Early	Total	
Double-stem Trellis	11,796	41,845	8,002	48,750	9,899	45,297	4.95
Flat Grown........	4,111	37,570	3,590	35,730	3,850	36,650	5.96

In taking the harvest records the first three pickings were considered the early portion.

There was some difference between results obtained at Waltham and at Amherst but part of this was due to soil type and weather. The season warms up faster at Waltham, thereby producing a larger yield of early fruit.

It is in the early yield that the trellis tomatoes show up to greater advantage. The trellised plots averaged a little over twice as much early fruit as the flat-culture plots. The Waltham average was even greater, for in two of the four years of the experiments the trellised plants produced four times as many early fruits. There was little difference in the size and quality of the early fruits, but for the complete harvest the fruits on trellis were larger.

A special set of grades was used in these experiments because of the preference of the Boston Market for small fruits: No. 1, fruit 2¼ inches and over in diameter, uniform in shape and color, and free from cracks; No. 2, 1½ to 2¼ inches in diameter, fairly uniform, and mostly smooth (shallow cracks allowed). All rough, small, catface, poorly colored and deeply cracked fruits were classified as culls. The Waltham Forcing variety of tomato is naturally quite uniform in size and shape, and produces a much smaller percentage of rough fruits than do the larger varieties.

The percentage of No. 1 fruit is very important to the grower, particularly in the early part of the season when prices are high. In the early yield the trellis plants produced 6 percent more No. 1 fruits. For the total crop the flat culture method was ahead in No. 1 fruits by 3 percent.

It is well known that where plants are trellised and supported, and exposed to wind and sun, more cracking of the fruit occurs. At Waltham the trained plants had 40 to 50 percent more cracking of fruits than those grown flat. Even with this high percentage of cracking, which automatically classed the fruit as culls, the trellised plants produced only 3 percent fewer No. 1 fruits than the flat grown.

The amount of cracking varies with the year and the season. There is very little in the early season while many times the last of the crop is severely affected In the years when the yield was large, there was usually a smaller percentage of cracked fruit, indicating that the factors which increase yield and growth also reduce the cracking.

From these experiments, and the experience of growers, it is evident that the amount of cracking will be small where the supply of moisture in the soil can be kept uniform and the plants and fruits constantly growing.

Varieties of Tomatoes for the Trellis

The selection of a variety of tomato for use on trellis depends to a marked extent upon the market demand. Boston pays high prices for the small, more uniform tomato of the Comet type, and when growers changed from flat culture to trellis they also shifted from varieties such as Marglobe, Bonny Best and Early Prolific. In general, the larger-fruited types, especially when grown on trellis, have not held their foliage in many seasons and, therefore, have not produced satisfactory yields.

Another factor that must be considered is the number of fruits per cluster. Comet generally produces a large number while the larger-fruited varieties produce only a few fruits per cluster; and when the plants are kept pruned, the number of these clusters is definitely limited so that the possible yield is reduced. Comet produces so many fruits that at times under poor cultural conditions the plant is not able to grow all of them to marketable size.

Breeding work with tomatoes has been under way at the Waltham Field Station of the Massachusetts Agricultural Experiment Station during the past eight years. The first tomato distributed for trial was the Waltham Forcing which was developed, as its name signifies, for the greenhouse. It is of the Comet type and was obtained by selection from the old English Best-of-All. The strain had been in this country for many years and had been used by local growers but the fruit had always been too small and the set of fruit was only fair. These characters were improved by selection through several generations, and the Waltham Forcing tomato is now the most important variety for greenhouse use in Massachusetts. Growers who used it inside also tried it on the trellis outside and it proved quite satisfactory. Now, a considerable acreage of this variety is grown.

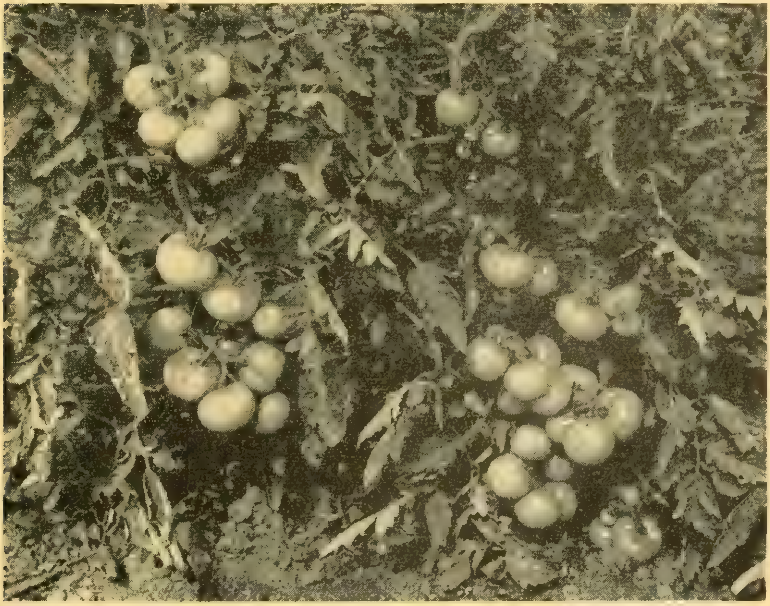


Figure 1. Trellis No. 22 Variety.

The other variety of tomato developed at this Station is Trellis No. 22, a cross between Waltham Forcing and Lloyd Forcing. It is a few days later in maturing than Waltham Forcing and on the Field Station plots does not yield as heavily; but the fruit is larger and it makes a little nicer pack for market. Figure No. 1 illustrates the type of growth and set of fruit produced by the Trellis No. 22.

The behavior of these two varieties is not consistent throughout eastern Massachusetts. In one section the Waltham Forcing is always larger and superior to the Trellis No. 22, which is just the reverse of the experience of most growers. When grown on trellis, the Waltham Forcing, Trellis No. 22, and other strains and selections of Comet averaged 4.5 fruits per pound for the season, Michigan State Forcing 3.6, Stokesdale 3.2, Bonny Best 3, Rutgers 2.8, and Marglobe 2.7. The total yields in a good growing year do not differ greatly, but the smaller varieties always produce a larger percentage of No. 1 fruits.

Selection of the proper variety is important for success with trellis tomatoes, and this selection cannot be made without considering the soil, fertilizing program, irrigation, market, and climate. A trial on the grower's own farm of several varieties that seem to fit the market needs is the only real solution to the problem. Varieties suggested for trial, in the order of their probable value on most of the Massachusetts farms are: Trellis No. 22, Waltham Forcing, Comet, Stokesdale, Michigan State Forcing, Bonny Best, and Marglobe.

The value of good seed cannot be overemphasized; and regardless of the variety selected it is important to obtain a uniform strain from a reliable source.

Plant Production

One of the most important factors in the successful production of tomatoes, whether grown on trellis or untrained, is to have good plants. There is no one best method of growing plants. The plant-growing facilities on each farm differ so that the problem is an individual one. It is probable that only after some experience will satisfactory plants be produced.

Every market gardener should have a small greenhouse or plant house in which to start seed and make the first transplantings. It need not be as large as the one shown in Figure 2. The advantages of such a structure over the manure-heated hotbed are many: better plants because of less disease, a chance to control the heat, easier ventilation, and a convenient place to work.

As soft, succulent growth does not stand hot drying winds during transplanting, plants should be adequately hardened. Proper timing in order to have the plants at the correct stage to set in the field at the right time depends to a large extent upon the weather. It should always be kept in mind that the weather may not be favorable just when it is planned to set the plants, and they may become overgrown. It is always better to set a small plant than one 2 feet tall. A good plant is 10 to 15 inches tall, stocky, with a large well-branched root system that will not break off when moved.

Every grower who contemplates changing from flat culture to trellis should remember that the number of plants required per acre more than doubles. More information about this is given under Spacing and Training Plants, page 15.

The time of year to start the seed is a much discussed question and each grower must decide according to his own conditions. Seed is planted from January 15 to April 10. The warmer the growing conditions, the later the plants may be

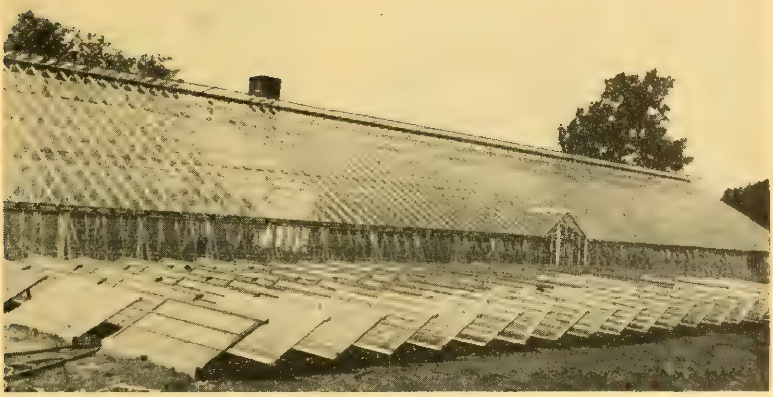


Figure 2. Adequate Plant Growing Structure.

started. As more growers have built better plant-growing structures, there has been a tendency toward later planting. At the Waltham Field Station seed is sown in flats in a 60° F. greenhouse usually about April 1. The plants are pricked out in benches in the same greenhouse 2 x 2 inches. When 4 inches tall, and about May 1, they are moved to the cold frame and set 4 x 4 inches or, if space is available, 6 x 6 inches. Figure 3 shows the stages at which the plants in this experiment were transplanted the first and second time.

Even when seed is planted as late as April 1, the plants are sufficiently large to set May 28 to June 1. If seed is sown thinly in the seed bed, the plants are not so likely to become spindly. One ounce of seed will produce at least 3,000 plants.

There are many different opinions as to how many times a plant should be transplanted. The more times the plant is moved the more branched and compact the root system becomes. Setting over twice, as practiced at the Waltham Field Station, has produced a very satisfactory plant.

"Are potted plants worth the cost and trouble?" is a frequent question. To obtain the answer, some plants were set in 4-inch clay pots at the time of transplanting to the cold frame. When ready to set in the field the pot was well filled with roots and the soil did not break apart. Figure 4 shows a well-grown pot plant.

Other plants were grown 4 x 4 inches apart in the bed. These were dug when the soil was very wet and a ball of soil was pressed around the roots of each plant.

The potted plants, which received no check in growth, produced the largest early yield. At Waltham this increase in yield amounted to 38 percent; while at Amherst the increase was much greater, being 83 percent. Since this early fruit is the part of the crop that brings the highest price, these increases are certainly worthwhile. The increase in total yield was not so great: 10 percent for Waltham and Amherst combined.

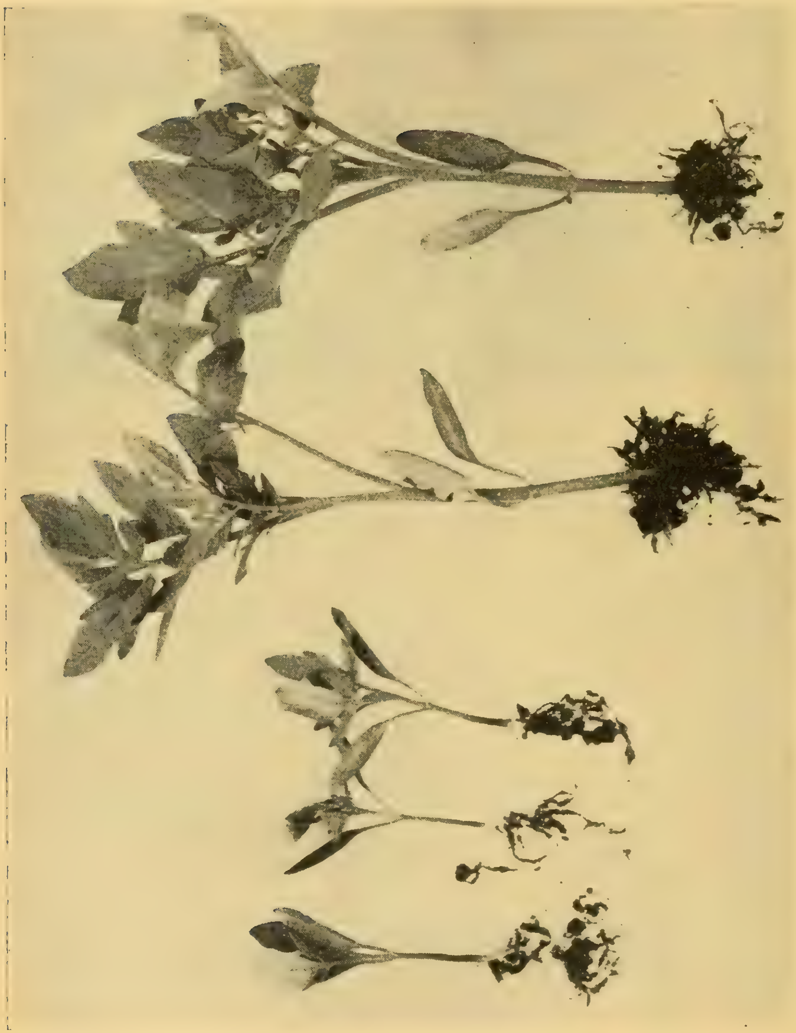


Figure 3. Stages of Growth When First and Second Transplantings Were Made.

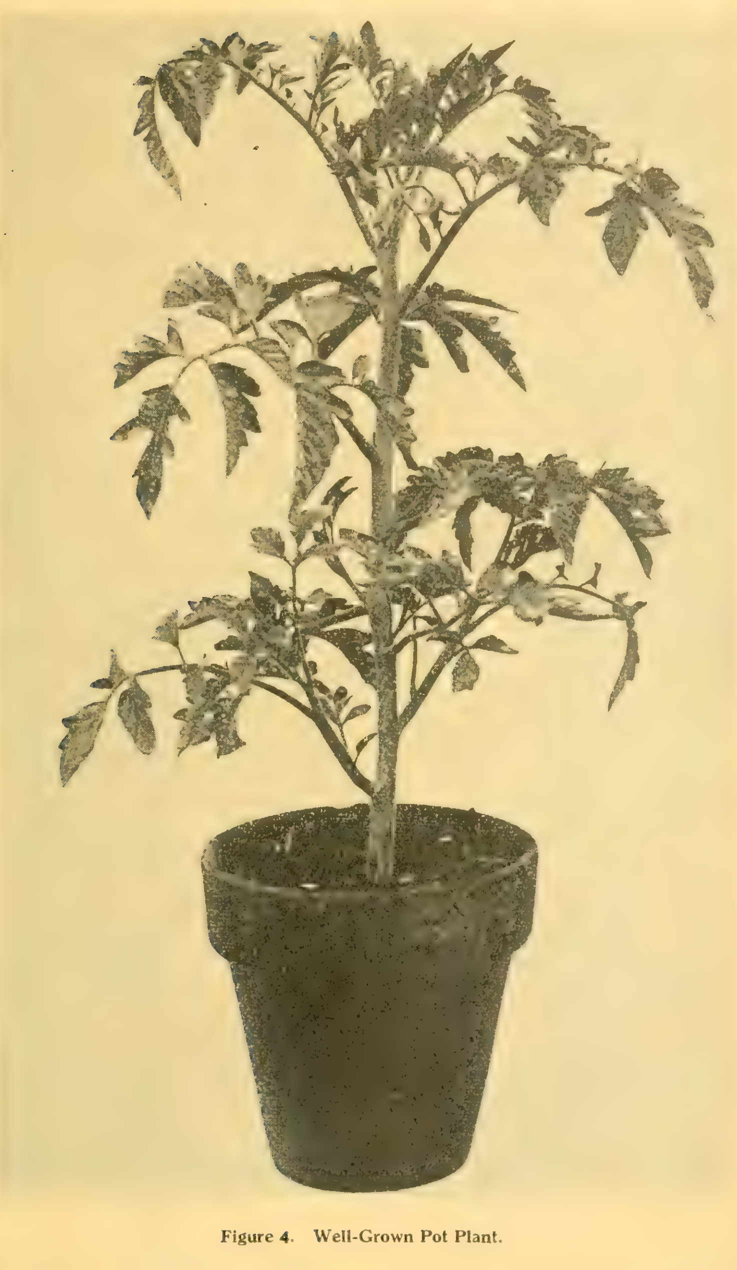


Figure 4. Well-Grown Pot Plant.

While the initial investment in clay pots is considerable, they will last for many years if properly cared for. One-quart strawberry baskets are a very good substitute for clay pots. They are not expensive and will produce almost as good a plant. However, these cannot be used again, so in the end it is cheaper to purchase the pots. There are many kinds of plant bands made either of wood or of treated paper which have proved very satisfactory.

Experimental evidence has shown that over-hardening the plants delays growth in the field and reduces the early yield. Some hardening is necessary, but the plants should be kept growing all the time to insure early growth in the field.

"Give the plant a good start" is not only a good slogan but a necessity for the market gardener who plans to make money growing early tomatoes.

Soil Preparation

For a crop such as trellis tomatoes, in which a considerable sum of money is invested, it is necessary to have the soil in the best possible condition. Many failures can be attributed directly to lack of fertilization and proper soil preparation.

It is important that this crop have a uniform supply of moisture and plant food throughout the season. Soils well supplied with organic matter, such as some of the older intensively cultivated areas around Boston, hold a good supply of both water and plant food.

Consider the soil available for growing tomatoes and determine its value as to water-holding capacity, texture, depth, organic matter, and residual plant food before deciding whether to trellis the crop. Certain of the lighter-textured soils can be used for trellis tomatoes if ample irrigation is available.

Many of the better growers have successfully followed the plan of turning under sod for their tomato crop. If this practice is followed, it must be good sod and on land that has previously been well fertilized.

Formerly, most growers used rather generous amounts of manure for tomatoes but as manure became scarce the question of its value for the production of a good tomato crop became increasingly important.

In the Waltham and Amherst experiments, most of the crop was given a coating of cow manure at the rate of 10 to 12 cords per acre. Certain plots received no manure while others received a double amount, with the heaviest treatment 20 to 25 cords per acre. The experimental plots were moved to a new area on the Station grounds each year so that there could be no cumulative effect. All plots received 1 ton of 5-8-7 fertilizer per acre broadcast. The yields on the three levels of manure are presented in Table 2.

TABLE 2. EFFECT OF MANURE ON THE YIELD OF TRELLIS TOMATOES.

Manure per Acre	Yield per Acre, Pounds						Percent of No. 1 Fruits at Waltham
	Waltham		Amherst		Combined Crop		
	Early	Total	Early	Total	Early	Total	
None	11,070	38,712	5,400	39,216	8,235	38,964	44.3
12 Cords	11,796	41,845	4,224	45,618	8,010	43,731	58.9
24 Cords	12,564	44,011	3,846	44,466	8,205	44,238	59.6

Differences resulting from the application of a medium and large amount of manure are not very great. A part of this may have been due to the fact that the soil, both at Waltham and Amherst, is well filled with organic matter. Also, ample irrigation was used at all times, which probably did not allow the moisture-holding qualities of the manure to show to full advantage.

Although the total yields at Waltham were not greatly influenced by the application of manure, it did have considerable effect on the percentage of No. 1 fruit. Much of this difference was due to less cracking and larger fruit—two factors which are very important from the marketing standpoint. At Amherst the application of manure in any quantity reduced the early yields, but the total yields were in favor of the application of a medium quantity of manure. The difference in the effect of manure on early yields in the two experimental areas is probably due to the different soil types and the speed with which the soil warms up in the spring. Had these experiments been conducted on lighter soils, the value of manure would undoubtedly have shown to better advantage.

It is probable that other kinds of manure, such as poultry, pig, or horse, would have produced slightly different results. This is particularly true of poultry manure because of the higher percentage of nitrogen that it contains. All types of manure can be used to advantage on tomtaoes if they are handled properly and the fertilizer is balanced accordingly.

Some growers have followed the practice of placing part or all of the manure in the furrow, but it is questionable whether this is worth the extra labor required. If the manure is evenly incorporated into the soil, a more even growth will be obtained and the land will be left in a uniform condition for the next crop.

Setting the tomato plants; putting up the trellis, wire and string; and spraying make it necessary to walk over the soil a number of times. If a good job of plowing and fitting the land is not done before these operations start, the soil becomes quite compacted. Proper soil preparation is important enough to justify taking time for a thorough job.

Before the preparation of the soil starts, consideration should be given to the need for lime. Better results from the fertilizer and manure will be secured if the soil is slightly acid (pH 5.8 to 6.5). If lime is to be applied it is essential that the application be even and uniform. Applying the lime just before or just after plowing will insure good mixing with the disk.

Fertilizer for Trellis Tomatoes

The production of large quantities of tomatoes per acre necessarily requires considerable amounts of plant food. If the soil cannot supply this plant food the crop will suffer in size of fruit, quality, and yield. A properly balanced fertility program will vary from farm to farm according to the type and natural fertility of the soil, the cover crops used, and the amount and kind of manure applied. In these experiments certain indications have been noted and will serve as a guide to growers in making up their own fertilizer program.

Amount of 5-8-7

In getting at the problem of the proper amount of fertilizer to apply, it was decided to use the most popular grade, 5-8-7. Three treatments were compared: no commercial fertilizer, 1 ton per acre, and 2 tons per acre. All of the plots received 12 cords of manure per acre.

TABLE 3. EFFECT OF THE AMOUNT AND KIND OF 5-8-7 FERTILIZER ON THE YIELD OF TRELLIS TOMATOES.

Treatment of Plots	Yields per Acre, Pounds					
	Waltham		Amherst		Combined Crop	
	Early	Total	Early	Total	Early	Total
No fertilizer	10,300	36,756	6,618	40,618	8,459	38,687
1 Ton 5-8-7 (Check Plot)	11,796	41,845	8,002	48,750	9,899	45,297
2 Tons 5-8-7	10,425	38,655	7,936	54,560	9,180	46,607
1 Ton 5-8-7 in row	11,742	41,560	7,416	54,364	9,579	47,962
1 Ton Special 5-8-7*	10,890	41,275	8,158	51,748	9,524	46,511
1 Ton 5-8-7+ ½ Ton Superphosphate	11,503	43,555	8,210	49,214	9,856	46,384
1 Ton 5-8-7+ Nitrogen Top-Dressing	11,724	41,231				

*¾ of nitrogen in organic form.

Table 3 shows the yields of tomatoes for these three levels of fertilizer at Waltham and Amherst. The application of 1 ton of fertilizer per acre produced the best results at Waltham, and 2 tons per acre definitely depressed both the early and the total yield. At Amherst, 1 ton of fertilizer per acre produced the greatest early yield but 2 tons per acre produced the largest total yield. It is evident from these results that each soil will respond differently to fertilizer treatment.

It is questionable whether the increase in yield obtained by using 2 tons of fertilizer would pay for the extra fertilizer. In fact, the plants produced remarkably well with no fertilizer at all except the 12 cords of manure. The importance of ample fertilizer in years of excessive rainfall, such as 1938, was emphasized; for that year the total yield of tomatoes from the plots that received 1 ton of fertilizer per acre was 29,430 pounds, while the plots that received no fertilizer produced only 14,974 pounds per acre. The early yield was in about the same ratio.

A good crop of trellis tomatoes will require approximately 1 ton of 5-8-7 fertilizer per acre. If the land is very rich, or if large quantities of manure are being used, then the amount of fertilizer can safely be reduced to 1500 pounds per acre. If the soil is poor or has very little residual fertility, then it would be best to apply 1 ton per acre at the time of planting and follow this with top-dressing during the growing season.

Extra Phosphorus

The value of adding extra superphosphate to the soil was tested in one treatment where the regular 5-8-7 fertilizer plus ½ ton of 16 percent superphosphate was applied. The yields from this treatment are also presented in Table 3. At both Waltham and Amherst the extra phosphorus did not affect the early yield and the increase in total yield was only slight.

New land or land that has not been kept to a high level of fertility might respond much better to extra phosphorus than the soils used for this experiment.

Row Application

Some growers have followed the practice of putting all or a part of the fertilizer in the row, working it into the soil to some extent before setting the plants. Almost all local growers set tomato plants by hand so it is not possible for them to use machinery to apply fertilizer in the row at the same time the plants are set. Some have put both fertilizer and manure in the row.

To test the value of row application, the ton of 5-8-7 fertilizer was dug into the top 6 inches of soil where the row was to be made. The results of this treatment are shown in Table 3. At Waltham the yields were not increased by having the fertilizer in the row, the amount of fruit produced being almost identical with that from the plots where the fertilizer was broadcast; at Amherst, there was a slight increase in total yields.

In general it is considered that when the fertilizer is applied in the row larger crops can be produced with less fertilizer than when it is broadcasted over the entire area. Since broadcasting can be done mechanically, it is less expensive than row application.

In some sections putting the fertilizer in bands alongside the row is much preferred to placing it in the row. If the roots of the plants in growing downward do not have to grow through the fertilizer there is much less chance of their being burned. This method of applying fertilizer has long been used with potatoes, and during the last two years of these experiments it was tried in comparison with broadcasting. One year the band method was inferior to broadcasting or row placement of fertilizer; but the other year it was superior to broadcasting and about the same as in-the-row treatment. In this connection it should be pointed out that plenty of irrigation was used to start the plants so there was probably no chance for the fertilizer in the row to burn.

The value of the row application depends to some extent on the amount of fertilizer applied. Five hundred pounds per acre would probably produce better tomatoes if placed in the row than if broadcast, but when a ton or more of fertilizer per acre is used in conjunction with manure, row application is of less importance.

In the light of the results of these studies it is questionable whether growers can afford to place the fertilizer in the row unless it can be done with machinery.

Organic Nitrogen

Growers have always been interested in the value of having a good portion of the nitrogen in the fertilizer in an organic form, particularly for long-season crops like tomatoes. In these experiments one treatment was included with a special 5-8-7 fertilizer in which three-fourths of the nitrogen was derived from an organic material such as tankage. The amount of fertilizer used was the same as the standard application. The use of this quantity of organic nitrogen depressed the early yield of tomatoes at Waltham slightly but there was no appreciable difference in the total yields. At Amherst the early yield was about the same, but the total yield was slightly greater than with the regular fertilizer as shown in Table 3.

It will require more experimental work to really determine the value of organic nitrogen for tomatoes. Since organic nitrogen costs about three times as much as chemical forms, the increase in yield must be decisive to justify its use.

Top-Dressing with Nitrogen

Long-season crops such as tomatoes are generally benefited by a top-dressing of nitrogen fertilizer during the growing season. Where heavy applications of complete fertilizer are made, the value of this top-dressing is questionable. Consequently, this treatment was included in the experiment.

Nitrate of soda was applied to the plots that received the regular manure and 5-8-7 fertilizer treatments. An application was made on July 10 and July 30, each at the rate of 300 pounds per acre. Records on this treatment were completed only at Waltham, and are presented in Table 3. Early and total yields for the plots top-dressed with nitrogen were just the same as for those receiving only the basic fertilizer application.

The failure of nitrogen top-dressing to increase the yield is probably due, as was the case with other fertilizer treatments, to the fact that 1 ton of the 5-8-7 supplied all the plant food that the plants could possibly use. If less fertilizer had been used, or if the soil had been less fertile, no doubt the top-dressing would have increased the yields. When tomatoes are planted on light, sandy soil heavy rains are likely to wash out all the soluble nitrogen and under these conditions top-dressing will be of value.

Double-Strength or High-Analysis Fertilizer

A special double-strength fertilizer was originally included in these experiments but its manufacture was discontinued. Two other treatments approximating double-strength 5-8-7 were used for short periods. The fertilizer was applied so as to provide the same amount of plant food as the regular 5-8-7. In all the work with these high-analysis materials the yields were about the same as those obtained from the use of single-strength material, or at times slightly higher.

When double-strength fertilizer materials are properly applied, it is evident that they will produce just as satisfactory yields as the single-strength.

Building the Trellis

The trellis to support the tomato plants can be constructed either before or after the plants are set. Most growers put in the plants, furrowing out with a plow to aid in the setting, and construct the trellis along the row after the plants have started to grow. If the trellis is put up before the plants are set, there will be no danger of damaging them with posts, wire, or tools; but when the plants are set the holes must be dug with trowel or shovel.

There are many types of trellis, but the most common is one having substantial end posts, such as 4 x 4 inch or 3 x 4 inch. (Figure 5.) These are anchored with a guy wire or stake 4 or 5 feet beyond the posts. The supporting posts are placed 15 to 25 feet apart along the row. These can be of 1-inch or larger pipe, 2 x 4's or 3 x 4's, but they must be strong enough to support considerable weight. The wire (No. 9 or 11) is then strung along the top of the posts. It should be stretched as tight as possible so that there will be little sag when the plants become heavy, and can be kept in place on the wooden posts by stapling, and on the pipe by inserting a loop of wire over it and into the pipe. A smaller wire, No. 18 or 19, along the bottom on which to tie the strings completes the trellis. It is generally considered better to have this bottom wire and to tie the strings somewhat tightly on the top and bottom wires than onto the plants. The string for supporting the plants should be a stout one, such as 3 to 5 ply jute or binder twine.

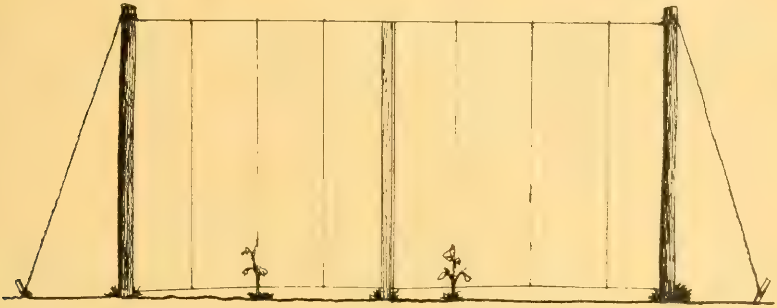


Figure 5. A Trellis for Tomatoes.

Stakes

If a supply of inexpensive stakes is available, it will probably be cheaper to use these than to build a trellis. When the plants are to be pruned to a single stem, a stake is driven beside each plant. If they are pruned to two stems, two stakes are needed. A disadvantage in using stakes is that the plant has to be tied to the stake, whereas with the trellis the plant is twisted around the string. It is difficult for inexperienced farm help to tie the string around the stake securely and yet keep it loose enough so that the plant has room to grow.

The manner of supporting the tomato plants will vary from farm to farm, depending upon materials, labor, and the preferences of the grower. The method used makes no difference in the yield or quality of the crop.

Spacing and Training Plants

Before the tomatoes are set in the field it is necessary to decide just how they are to be trained and spaced. In these experiments it was not possible to include plots in which the plants were given different spacings except in relation to the number of stems. The distances were 12 inches for plants trained to a single stem, 21 inches for plants trained to two stems, and 4 feet for untrained plants. The distance between the rows was 4 feet.

A new method practiced by one grower was to vary the distance between the rows by placing two rows close together (2 feet) and then allowing 6 feet to the next row. That allowed space between rows to drive small tractors for hauling spray equipment and wagons to pick up the fruit.

There has always been considerable discussion among growers as to which is more advantageous, pruning the plants to one or two stems. The results of these experiments with the two types of pruning are presented in Table 4. Both at Waltham and at Amherst the plants 12 inches apart and pruned to a single stem produced the largest yield of early fruit and the greatest total yields.

TABLE 4. EFFECT OF TWO SYSTEMS OF TRAINING PLANTS ON THE YIELD OF TRELLIS TOMATOES.

Treatment	Waltham		Amherst		Combined Crop	
	Early	Total	Early	Total	Early	Total
			Yield per Acre, Pounds			
Single Stem.....	16,446	45,360	7,748	53,311	13,097	49,335
Double Stem....	11,796	41,845	8,289	47,487	10,042	44,666
			Yield per Plant, Pounds			
Single Stem.....	1.52	4.20	.63	4.93	1.07	4.56
Double Stem....	1.96	6.97	.90	7.91	1.43	7.44

Only the lower cluster of fruit on the plant was included in the early yield, and each plant has only one such cluster regardless of how pruned. Branching for the two stems usually took place near or above this first cluster. Therefore, the single-stem plants set 10,000 to the acre had a larger number of clusters of early fruit than the two-stem plants set 6,200 to the acre. When considered on the basis of production per plant, those pruned to two stems had the highest early and total yield.

The method of training the plants made very little difference in the size of the fruit. The larger yield of early fruit as a result of pruning to a single stem is important, but growers should not lose sight of the fact that a greater number of plants per acre is necessary.

It would seem that a grower located on high-priced land should provide himself with adequate plant-growing facilities and train the plants to a single stem, since this method returns the largest profit per acre. Growers whose land is not so valuable could train the plants to two stems and get more fruit from each thousand plants grown.

With these facts in mind, each grower can survey his land and plant-growing facilities and decide which training method best suits him.

Pruning

After the trellis is up, the strings are on the wire, and the plants have started to put out new growth, it is time to begin pruning. Figure 6 shows a plant at the proper stage to start pruning.

The tomato plant has one central shoot or leader. At each joint or leaf, a shoot comes out and if these are allowed to grow, the plant will produce a large bush with many stems which cannot be tied up or supported on trellis. If the plants are to be pruned to a single stem, only the central shoot is allowed to grow. The side shoots, or suckers as they are sometimes called, that appear at each joint are removed when they become 2 to 4 inches long. Pruning delayed until the side shoots are 6 inches long reduces the vigor of the plant.

If the plant is to be pruned to two stems, the central shoot and one side shoot are allowed to grow and the remainder are removed. One side shoot will be found more prominent and vigorous than the others, and if this is not over 10 inches from the ground it is the best one to leave.

It is necessary to prune the plants, and twist the stems around the string, every week during the early period of rapid growth.

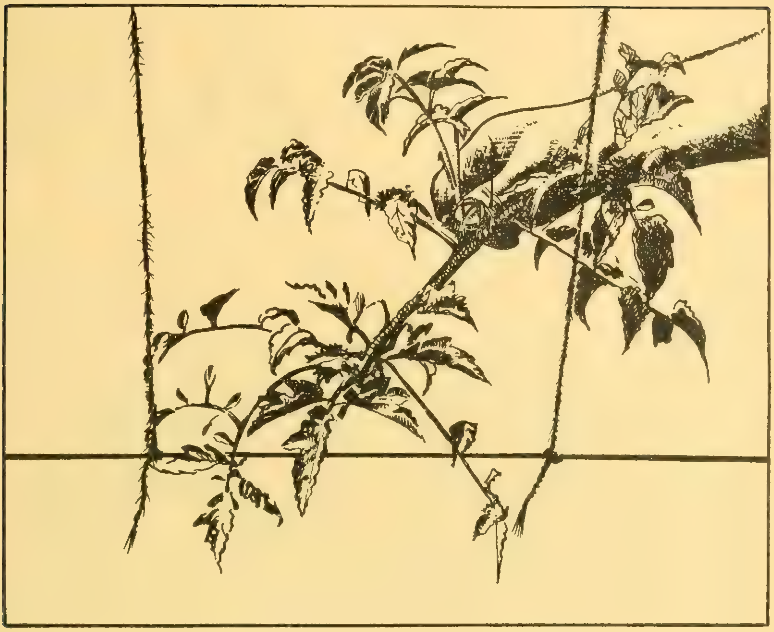


Figure 6. The Proper Stage to Start Pruning.

Cultural Practices

Cultivation

Early in the season trellis tomatoes need to be cultivated to keep down the weeds. Cultivation should be shallow because deep stirring of the soil cuts many of the roots. Unless there are weeds to be killed, do not cultivate.

Irrigation

Facilities for irrigating are desirable on the best market-garden land and almost a necessity on the lighter soils. In these experiments all the plots were irrigated when necessary. It was not practical to include plots which received only rainfall.

Mulching

The addition of a mulch helps to maintain a uniform supply of moisture in the soil. It was tried in these experiments for one year and the early yields were about the same with and without mulch, but the total yield was slightly better on the mulched plot.

Not many growers have mulching material and, of course, the cost of application is high, but if there is no water available for irrigation a mulch should be considered. Banana stalk fiber was used in these experiments but straw, hay, sawdust, peat, or similar material makes a satisfactory mulch. The use of some of these, however, requires extra nitrogen to prevent the decaying material from robbing the plants of the available nitrogen.

Insects and Diseases

The control of insects and disease is important for successful culture of tomatoes. Control of the flea beetle and early and late blight are particularly important. Up-to-date information on the control of both insects and diseases will be found in Leaflet No. 116 of the Massachusetts State College, "Control Calendar for Vegetable Pests."

Cracking of Fruit

The results of these experiments confirm previous experimental work and the observation of growers that trellising tomatoes increases their tendency to crack. The work with varieties indicates that those with a small amount of foliage are most susceptible to cracking.

Cracking of fruits probably cannot be eliminated entirely but several growers have shown that it can be kept to a minimum. Some of the practices that reduce the amount of cracking are:

1. Select land that does not dry out readily and that is well supplied with organic matter.
2. Keep the soil moist at all times. Most cracking is due to uneven periods of growth and swelling of the fruit.
3. If no irrigation is available use a mulch, if possible.
4. Provide sufficient plant food either before planting or as top-dressing to keep the plants growing steadily.
5. Harvest fruit at the pink stage.

Harvesting and Marketing

Picking of the tomatoes where the plants are trellised is not so difficult as with flat-grown plants but it is necessary to use care not to pick too green or to bruise the fruit. Since trellis tomatoes are quite firm, there is likely to be more carelessness in handling. During warm weather, it is necessary to pick every two or three days in order to prevent the fruit from becoming over-ripe for handling.

The fruit is usually picked into baskets and then carefully transferred to bushel boxes at the end of the row. Most of the preparation for market is done at the packing shed. If more than an acre of trellis tomatoes is grown, it will probably pay the grower to obtain a mechanical wiper to remove spray residue and brush off any loose dirt. Some growers have found it an advantage to pack from a moving belt in line with the wiper; others pack from tables.

There are two common packages in which tomatoes are marketed — the 12-quart basket with handle and the half-bushel box. The former, which is illustrated in Figure 7, is the more popular.

The basket makes an attractive package but it is hard to pack on the truck or to ship. The half-bushel box can be loaded on the truck without difficulty. Cellophane on the top of the basket, held in place by a large elastic, is widely used to dress up the package, particularly at times when prices are high.

The yield of trellis tomatoes ranges from 1200 to 2500 baskets per acre.

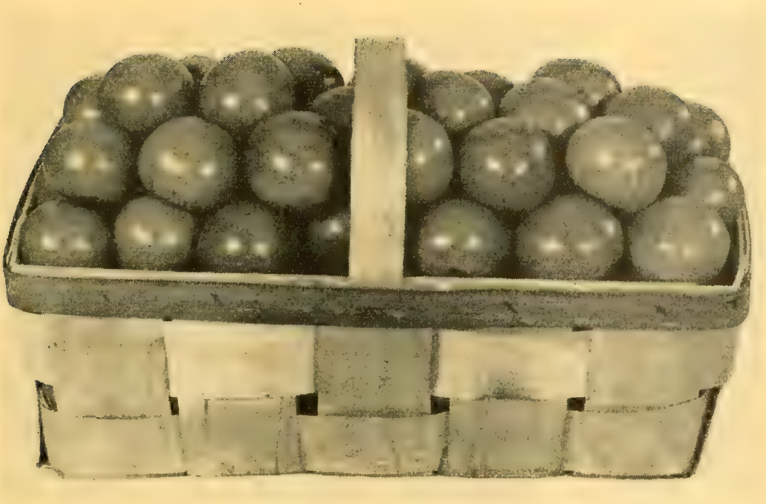


Figure 7. One Type of Package Used on Boston Market.

Publication of this Document Approved by Commission on Administration and Finance
4M (a) 12-44-15376

MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

MAY 10 1945

Bulletin No. 420 November, 1944

Mortality Studies in Rhode Island Reds

By F. A. Hays

Mortality from all causes is one of the most important problems of poultrymen. This report is intended to add something to the very limited information on the role of breeding in reducing mortality.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

MORTALITY STUDIES IN RHODE ISLAND REDS[1]

By F. A. Hays
Research Professor of Poultry Husbandry

INTRODUCTION

The problem of mortality is of vital concern to all poultrymen. Although great strides have been made in the prevention and control of diseases, losses from a wide range of diseases and disorders are still very heavy. It is estimated by the Bureau of Agriculture Economics that the annual loss of chickens in the United States in cash value is over 130 million dollars. About 40 percent of these losses are probably due to the avian leukosis complex. It is a common belief that selective breeding can do much to reduce the mortality rate. Frateur (1924) was one of the first to attempt to breed chickens for resistance to a specific bacillus. By inoculating with fowl diphtheria in the mucous membrane of the mouth he discovered resistant and susceptible birds. Matings were made to produce an F_1 generation which was tested by direct inoculation. An F_2 generation was also secured and tested as well as some back-crosses. Results of these studies led to the conclusion that resistance was due to a single dominant gene.

Significant progress has been made in breeding chickens for resistance to pullorum disease. Roberts and Card (1935) carried a strain of chickens through a nine-year period that showed an average survival of 71 percent to lethal doses of *S. pullorum*, while control chicks showed an average survival over the same period of 28.1 percent. Crosses between resistant and susceptible strains indicated a dominance of resistance. Resistant chicks had a high erythrocyte count while susceptible strains had a high leukocyte count. There was no evidence of acquired immunity in the different lines. Lambert (1932) selectively bred chickens for high resistance to lethal doses of fowl typhoid bacterium, *S. gallinarum*. In five generations the resistant strain had a mortality rate of only 9.4 percent, while the control stock had a mortality rate above 85 percent during the same period. A difference was also observed between breeds: Rhode Island Reds were the least resistant, and White Plymouth Rocks the most resistant of four breeds tested. Lambert states that the evidence points to inherited resistance and that passive transfer of immunity was not great. By selective breeding of mice, Hetzer (1937) reduced the mortality rate from injections of *S. aertrycke* from 98 to as low as 7 percent. He points out that resistance to this organism is inherited on a multiple factor basis. Gowen and Calhoun (1943) studied the blood cells of six strains of mice and found a pronounced correlation between resistance to mouse typhoid, *S. Typhimurium*, injections and numbers of leukocytes.

Experimental data on the mode of inheritance of resistance and susceptibility to virus diseases are very meager. This is due in no small degree to the difficulties in isolating viruses. The causative agents of the avian leukosis complex have been but partially identified.

Asmundson and Biely (1932) and Biely, Palmer and Asmundson (1932) made the first attempts to study the mode of inheritance of resistance to fowl paralysis. These workers noted a difference in susceptibility among the seven breeds tested.

---

[1] These studies have been made possible by the constant interest and cooperation of the Department of Veterinary Science.

Single Comb White Leghorns and Rhode Island Reds appeared to be the most susceptible. Under natural infection the disease occurred in about one-fourth of the pullets in families where it appeared. This fact pointed to resistance as being due to a single dominant gene. Artificial inoculations were also made and these tended to support the idea of differences in resistance between families.

McClary and Upp (1939) concluded that the iritic type of paralysis was transmitted through the egg. They also noted a higher incidence of the disease in progeny of iritic parents.

Hutt, Cole and Bruckner (1941), in four years of selective breeding for high and low resistance to the avian leukosis complex, have shown an incidence of 26 percent in the low line compared with 12 percent in the high line between the ages of 160 and 500 days.

Jeffrey, Beaudette and Hudson (1942) report results of selective breeding of White Leghorns for high and low resistance to the avian leukosis complex through seven generations. A marked decline in the incidence of the complex was observed in both lines, but the line selected for freedom from the complex had a significantly lower incidence than the line selected for high incidence. Mortality from all causes was still excessive in both lines at the close of the experiment.

Taylor, Lerner, DeOme and Beach (1943) bred two lines of Leghorns: one for high resistance and another for low resistance to the avian leukosis complex. A significant difference was observed between the lines throughout the period. There was no decline in the incidence of the disease in the resistant line throughout the period. After one year of selective breeding for low resistance no significant change in incidence of the disease appeared. There was also a parallelism between the two lines in the incidence of the disease.

DeOme (1943) concluded, after extensive injections of lymphomatous nerve tissue into resistant and susceptible chickens, that the relative resistance or susceptibility of the two strains was due to the action of numerous genetic factors.

Lee and Wilcke (1941), by inoculations with blood from chicks from stock affected with iritis into susceptible chicks, produced the disease in 67 percent of these chicks up to twelve months of age. Control chicks not inoculated showed no manifestation of the disease.

Work at the Regional Poultry Research Laboratory (Winton, 1943) showed that the avian leukosis complex may be transmitted through the egg and that there is a striking difference in the incidence of the disease in different families. There is also evidence that disease-free families may be developed through selective breeding and quarantine and that males are less susceptible to natural infection than females.

Marble (1939), through five years of selective breeding with White Leghorns and Barred Plymouth Rocks, improved the viability during the growing period and reduced the mortality rate for females in the laying house by 50 percent.

Bearse and McClary (1939) report the results of eight years' selection to produce high and low viability lines in White Leghorns. The two lines differed significantly in mortality from all causes during the growing period and during the first laying year.

Sturkie (1943) selectively bred White Leghorns to establish a line showing high viability during the first laying year. The initial mortality rate of pullets in the laying house was 89 percent. In five years the mortality rate had been reduced to 27 percent. At the beginning of the experiment about two-thirds of the deaths were due to leukosis and in the last generation about 14 percent died from this cause. It was concluded that superior inbred families were developed that exhibited high livability and satisfactory egg production.

Bostian and Dearstyne (1944) studied the results of selective breeding of White Leghorns for high livability over a five-year period and concluded that selective breeding was effective in reducing mortality from all causes in pullets between the ages of three and twelve months. Inbreeding was shown to increase the mortality rate.

Bryant and Johnson (1944) bred White Leghorns for high and low mortality from all causes. They report an insignificant difference in mortality rates between the two lines for the first eight weeks, when all dead chicks were included. The differences in death rates in pullets for the period from eight to twenty weeks of age was also of questionable significance. During the adult period, from five to seventeen months, the mortality rates for pullets from all causes were 25.66 percent and 36.34 percent respectively for the low and high mortality lines. The significance of the difference in adult mortality rates when all dead birds are included is not reported. The incidence of the leukosis complex was 9.06 percent in the high mortality line compared with 2.99 percent in the low mortality line.

Waters and Prickett (1944) were successful in developing a strain of White Leghorns that was free from the avian leukosis complex as long as the birds were kept isolated. Through contact exposure with other birds a high incidence of the complex appeared.

Nelson and Thorp (1943) pointed out that ocular lymphomatosis should not be considered as dissimilar to visceral or nerve types of the complex; and therefore birds with the eye type of the leukosis complex should be considered dangerous disseminators in the flock until conclusive evidence to the contrary is produced.

Materials and Methods

This report covers eight generations hatched from 1935 to 1942 and includes all pedigreed experimental stock. The major portion of the birds were purebred Rhode Island Reds. The control group and the high and low mortality lines included only Rhode Island Reds. Other experimental birds were chiefly Rhode Island Reds, but a few crosses between Rhode Island Reds and Barred Plymouth Rocks and between Rhode Island Reds and Buff Oprington were included. The study was divided into two phases: mortality records to the age of 18 months and probable causes of death from 8 weeks to 18 months of age.

All stock was reared together and pullets and cockerels were removed from the range at about 6 months of age. Sexes were separated at 8 weeks so that the period of observation included: (1) First 8 weeks when the sex was unknown; (2) growing period from 8 weeks to 6 months when the sexes were known; (3) an adult period from 6 months to 18 months of age.

The control line was selectively bred for characters affecting fecundity and an attempt was made to include low mortality rate in the family as one of the characters to select for. High mortality rate from all causes was the sole basis of selection in the high mortality line without inbreeding. Low mortality rate was the sole basis of selection in the low mortality line. All males and all females were retained to the age of 18 months in the last six generations of the high and low mortality lines.

Necropsies on as large a proportion as possible of sick and dead birds throughout the period were made by the Department of Veterinary Science. Unfortunately a considerable number of dead birds were not submitted for necropsy, among them a significant number that appear to have died from cannibalism.

The method of management was essentially as follows: All chicks were taken from the incubator to 10 x 12 coal-heated brooder houses on the range. A four-year range rotation was regularly used. Chicks from all experiments were hatched and housed together, usually about 225 in each house. The sexes were separated at eight weeks of age and the males removed to summer shelters while the pullets remained in the original houses. As pullets approached sexual maturity in September they were taken to the laying houses. The average age at housing was about six months. Cockerels were taken to winter quarters about the end of September and housed in large units. All chicks received pox vaccine when 10 to 12 weeks of age, and all stock was free from pullorum disease throughout the period. No outside birds were ever brought on the premises and visitors were excluded. Some hatching eggs from outside sources have been brought in. In January some breeding pullets were removed to breeding pens, some of them being placed in pens with old hens. Near the end of April these breeding pullets were returned to the laying houses. In June all females were removed to summer laying shelters to complete their first laying year. Cockerels remained in the same quarters up to January and then were shifted about for breeding purposes through the month of April. They were then assembled in larger units until the following fall when the period of observation ended. In the control and miscellaneous groups two or three cockerels from each selected family were retained after 6 months of age. In the high and low mortality lines, however, all cockerels hatched were retained for observation between the ages of 6 and 18 months in the last six generations and were housed as one large unit in a separate house from other cockerels.

EXPERIMENTAL RESULTS

Consideration will be given first to the mortality phase of this experiment. Mortality rates are considered for three periods: namely, the first 8 weeks, from 8 weeks to 6 months of age, and from 6 to 18 months of age.

Mortality Rates from Hatching to Eight Weeks of Age

In the controls the mortality of all chicks ranged from 2.03 to 7.66 percent, with a mean mortality of 5.21 percent for the seven generations reported. The generation hatched in 1936 was not included because of abnormal losses caused by fire and accident. No consistent change in the mortality rate was observed through an eight-year period. The high mortality line showed a consistently higher mortality rate than the control line and much higher than the low line, except for the generation hatched in 1938. There is no evidence to account for the excessive losses in the low line in 1938. Mortality rate in chicks in the miscellaneous experiments was intermediate between that of the controls and that of the high mortality line. (Table 1A and Chart 1.)

There is no evidence from these data that selective breeding will reduce young chick mortality.

Mortality Rates from Eight Weeks to Six Months of Age

The sexes were separated at 8 weeks of age and the number of males was greatly reduced at that time. The general policy was to retain almost all of the females to the age of 6 months. All mortality rates were based on the number of chicks at the beginning of a period and the number that died during that period. The mortality rates are reported separately for the sexes and for the sexes combined.

TABLE 1.—MORTALITY RATES IN FLOCKS HATCHED FROM 1935 TO 1942, INCLUSIVE.

	1935		1936		1937		1938		1939		1940		1941		1942		Mean Mortality Rate %
	Number of Chicks	% Mortality	Number of Chicks	% Mortality	Number of Chicks	% Mortality	Number of Chicks	% Mortality	Number of Chicks	% Mortality	Number of Chicks	% Mortality	Number of Chicks	% Mortality	Number of Chicks	% Mortality	
A. Mortality Rates from Hatching to Eight Weeks																	
Controls	838	2.03	—	—	1240	7.66	1350	4.74	1125	5.51	1286	4.82	881	4.43	745	7.25	5.21
High Mortality	51	0	—	—	64	14.06	155	10.97	155	12.26	73	6.85	189	4.76	150	9.33	8.32
Low Mortality	58	3.45	—	—	50	2.00	251	23.11	137	6.57	198	6.06	180	.56	155	3.87	6.52
Miscellaneous	2050	3.27	—	—	1845	7.53	1840	6.85	1783	9.70	1586	8.20	1707	5.68	2033	11.85	7.58
B. Mortality Rates from Eight Weeks to Six Months.																	
Controls																	
Males	116	5.17	—	—	236	3.81	316	3.80	127	3.15	192	5.21	145	5.52	131	6.87	4.79
Females	291	2.06	—	—	532	1.88	615	2.76	481	2.91	596	3.19	411	7.54	284	6.69	3.86
Totals	407	2.95	—	—	768	2.47	931	3.11	608	2.96	788	3.68	556	7.01	415	6.75	4.13
High Mortality																	
Males	17	0	—	—	30	3.33	72	5.56	64	4.69	31	3.23	94	7.45	75	8.00	4.61
Females	33	0	—	—	25	0	66	6.06	72	2.78	37	0	85	4.71	61	9.84	3.34
Totals	50	0	—	—	55	1.82	138	5.80	136	3.68	68	1.47	179	6.15	136	8.82	3.96
Low Mortality																	
Males	35	17.14	—	—	24	12.50	94	19.15	50	0	91	7.69	84	2.38	77	3.90	8.97
Females	18	0	—	—	25	4.00	98	7.14	77	3.90	95	9.47	93	1.08	72	2.78	4.05
Totals	53	11.32	—	—	49	8.16	192	13.02	127	2.36	186	8.60	177	1.69	149	3.36	6.93
Miscellaneous																	
Males	416	6.97	—	—	414	3.86	554	5.23	348	3.74	437	4.35	396	9.60	401	5.99	5.68
Females	843	2.73	—	—	836	1.32	862	5.80	690	2.75	727	3.85	773	7.76	728	3.30	3.93
Totals	1259	4.13	—	—	1250	2.16	1416	5.58	1038	3.08	1164	4.04	1153	8.50	1129	4.25	4.53

C. Mortality Rates from Six to Eighteen Months

Controls																
Males	—	—	—	—	40	35.00	26	30.77	25	36.00	20	40.00	34	44.12	23	39.13	37.50
Females	135	20.00	168	10.71	228	13.60	194	32.47	200	29.50	228	28.51	199	41.21	189	24.34	25.04
Totals	—	—	—	—	268	16.79	220	31.82	225	30.22	248	29.44	233	41.63	212	25.94	29.31
High Mortality																
Males	—	—	—	—	12	50.00	7	14.29	47	48.94	30	30.00	47	36.17	69	69.57	41.50
Females	33	12.12	36	16.67	23	13.04	43	46.51	46	26.09	33	3.03	47	19.15	55	30.91	20.94
Totals	—	—	—	—	35	25.71	50	42.00	93	37.63	63	15.87	94	27.66	124	52.42	33.55
Low Mortality																
Males	—	—	—	—	10	10.00	8	25.00	41	14.63	61	57.38	57	33.33	74	66.22	34.43
Females	18	0	29	10.34	15	46.67	49	46.94	44	56.82	59	18.64	56	17.86	67	7.46	25.59
Totals	—	—	—	—	25	32.00	57	43.86	85	36.47	120	38.33	113	25.66	141	38.30	35.77
Miscellaneous																
Males	—	—	—	—	82	40.24	78	34.62	99	48.48	79	50.63	82	51.22	77	58.44	47.27
Females	579	14.16	532	17.29	501	15.37	483	30.02	412	27.67	377	27.59	369	31.98	343	27.99	24.01
Totals	—	—	—	—	583	19.04	561	30.48	511	31.70	456	31.58	451	35.48	420	33.57	30.31

CHART 1.
MORTALITY RATES
FIRST 8 WEEKS

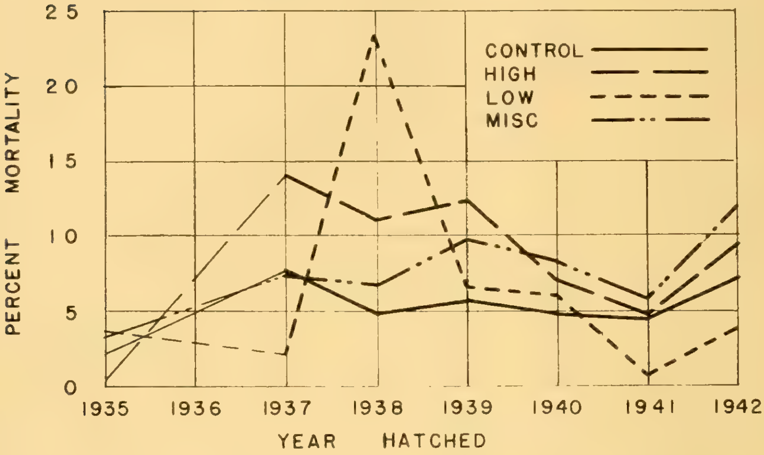
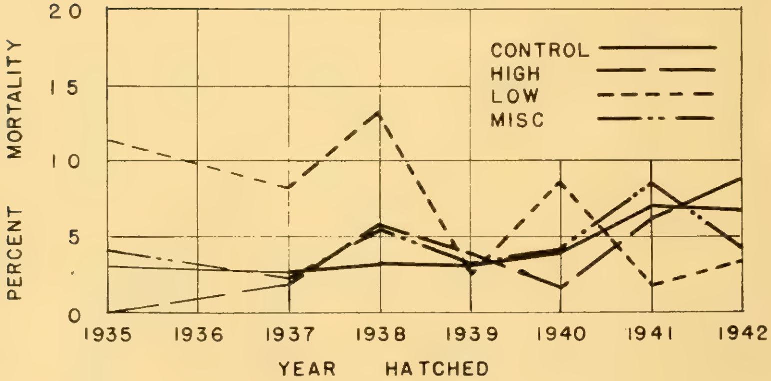


CHART 2
MORTALITY RATES
8 WEEKS TO 6 MONTHS
SEXES COMBINED



Two points are of vital interest in the consideration of the data: First, has there been a progressive increase or decrease in mortality rate during the eight-year period? Second, was there a significant difference in the mortality rates in the four lines?

The data (Table 1B and Chart 2) show a consistently higher mortality rate in males than in females during the period from 8 weeks to 6 months of age. This is in agreement with the observations of a number of workers.

The mean mortality rates for all chicks in each of the four lines over the eight-year period were fitted to a straight line by the method of least squares and the standard error around this line was calculated. The data actually fitted a straight line since a dispersion of twice the value of the standard error included more than 95 percent of the actual values. On this basis a consistent upward or downward trend in mortality rates for the experimental period could be noted.

The significance of the rate of change was tested by the method of Van Uven suggested by Pearl (1940). The standard error of the slope was calculated to test its significance. Fisher's t test cannot be used to compare mortality rates in the different lines, because this test gives no consideration to the element of time, which is vitally important in all experiments where different lines are developed through a period of years.

The control line showed an increase in mortality rate during the experimental period from a calculated initial value of .90 percent in 1935 to a calculated final value of 6.36 percent in 1942. This line had a positive slope of .78 ± .148. This increase is statistically significant because the slope is more than five times its standard error. The high mortality line also showed a very significant increase in mortality rate. The initial calculated rate was −.25 percent and the final calculated rate was 7.17 percent. The rate of increase was 1.06 ± .136 percent. The line bred for low mortality did not behave consistently during the experimental period. There was a calculated initial mortality of 8.42 percent and a final value of 3.73 percent. The rate of change measured by the slope was −.67 ± .456. There was definitely no significant decline in mortality rate in this line. In the miscellaneous group an increase in mortality rate was observed. There was a calculated rate of 2.03 percent in 1935 compared with a calculated final rate of 5.88 percent. The rate of increase was represented by a slope of .55 ± .264. The odds are about 20 to 1 that this increase was significant.

In general, these data indicate that there was a tendency for the mortality rates to increase in three lines during this experimental period. Although the mortality rate in the low line did not increase, neither did it exhibit a significant decline. In other words, there was no significant change in mortality rate in the line selected for low mortality. It seems probable, therefore, that selective breeding was effective in preventing any increase in mortality rate in this line despite the abnormally high rate shown in 1938.

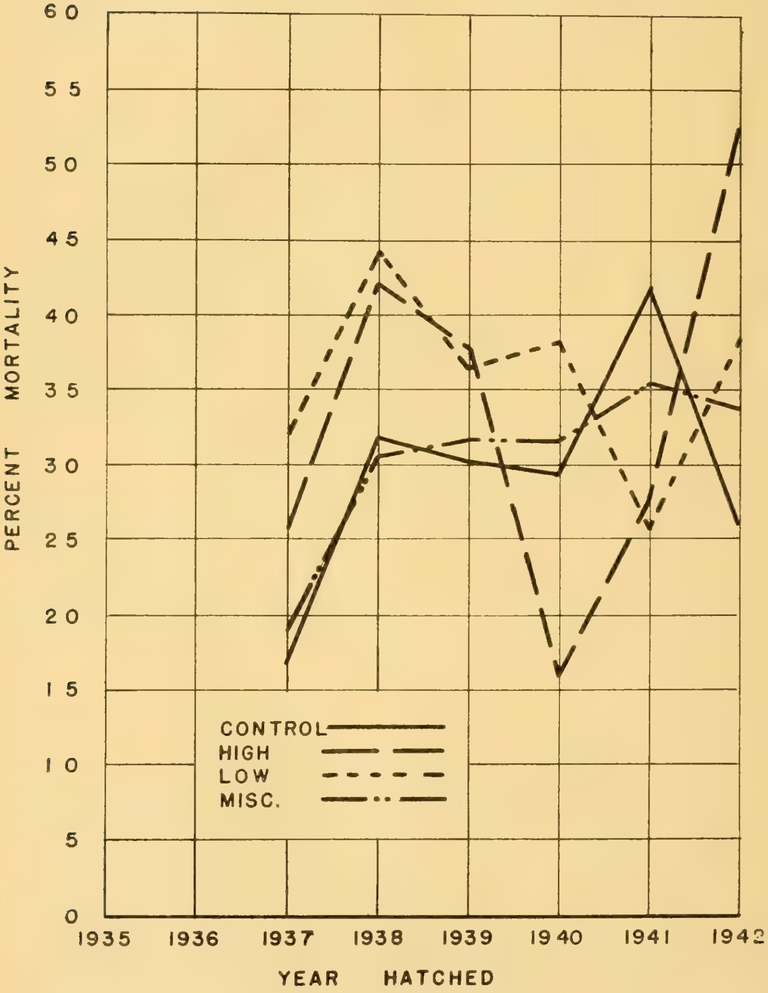
Comparison of Changes in Mortality Rates

Since the rate of change in mortality rates has been calculated for each line between the ages of 8 weeks and 6 months, it is possible to determine whether the rates of change in the lines have been different through the experimental period. The difference in the rate of change between the high and low mortality lines is of greatest interest. In this instance the difference between the slopes of the two lines was 1.06 − (−.67) or 1.73 ± .48. Since the difference is more than three times the standard error of difference, it appears that the two lines do differ significantly in their rate of change in mortality rate.

A comparison of the high mortality line with the control line gave 1.06 − .78 or .28 ± .20. In this instance the difference was scarcely greater than the standard error of difference and was clearly not significant.

When the low mortality line was compared with the control line, the values were .78 − (−.67) or 1.45 ± .48. In this comparison the difference is three times the standard error of difference and is therefore significant. It is logical to assume that the low mortality line differed significantly in mortality rate from both the high mortality line and the control line.

CHART 3.
MORTALITY RATES
6 TO 18 MONTHS
SEXES COMBINED



Adult Mortality Rates Between the Age of Six Months and Eighteen Months

Mortality records were secured on a limited number of males between the ages of 6 and 18 months. The males in the different experiments were usually housed together in rather large units. Females were placed in the laying houses at about 6 months of age. These pullets were divided into three 30 x 30 laying houses according to age. No culling was practiced and all were trapnested as long as retained.

Mortality rates for the adult period are reported by generations in table 1C and presented graphically in chart 3.

Males consistently showed a higher death rate than females in all four lines. There is no question but that the male death rate was greatly increased by injury from fighting. This will be further considered in the next section.

Adult mortality rates in the four lines were tested for significant changes by the method of Van Uven (Pearl, 1940). The control line had a calculated mortality rate of 23.98 percent in 1937 and 36.76 percent in 1942. The rate of change as measured by the slope was 2.13 ± 1.217. An increase in mortality rate was, therefore, only apparent since the slope was not much greater than its standard error. The high mortality line fluctuated very widely through the six-year period. The slope of its mortality rate line was 1.96 ± 2.038 percent. It seems logical to assume, therefore, that no significant change in mortality rate occurred during the period of observation. The mortality rate in the low line remained rather stable through the six-year period. There was a slight downward trend which proved to be insignificant. The slope was −.61 ± 1.077. The miscellaneous group of birds exhibited a rather definite increase in mortality rate during the experimental period. The initial calculated rate was 24.01 percent and the final calculated rate was 39.25 percent. The slope of this line was 2.54 ± .827 which is clearly a significant slope.

In general, when the mortality rates are considered for the combined sexes, no significant changes were observed in the control, high, or low lines; but the miscellaneous group showed a significant increase in the six-year period. These data fail to indicate that selective breeding as carried on was effective in reducing deaths from all causes between the ages of 6 and 18 months.

Comparison of Changes in Mortality Rates

A study and comparison of the rates of change in mortality between the ages of 6 and 18 months is important. When the high and low mortality lines were compared in rate of change the difference was 1.96 − (−.61) or 2.57 ± 2.31. This difference is just above the standard error of difference and is not significant. A comparison of the high mortality line with the control line showed a difference of 2.13 − 1.96 or .17 ± 2.37. There was no evidence of any difference here. The low mortality line and the control line were next tested for difference, which proved to be 2.13 − (−.61) or 2.74 ± 1.63. Here again there was no significant difference between the two lines with respect to rate of change in mortality rate.

These facts further point to no significant differences between the high, low and control lines in mortality rate between the ages of 6 and 18 months.

CAUSES OF DEATH

Sick or dead birds were sent to the Department of Veterinary Science for necropsy. It is believed that the birds examined represent a fair cross section of the different lines. The majority of diagnoses were made on gross autopsy records and an attempt has been made to classify the birds examined with respect to the diseases or disorders observed. Obviously some individuals showed more than one disorder so that when the percentages of birds showing the different diseases or disorders are added for a particular line, the sum may exceed 100. Birds younger than 8 weeks were not examined.

Necropsy Records for Birds from Eight Weeks to Six Months of Age

A relatively small percentage of sick and dead birds was sent in for necropsy. During the growing season of 1936 fire and accidents disturbed the normal mortality rate so that the data for that year are omitted. In table 2 the necropsy records secured on the dead birds examined are presented. It is thought that these records give a fairly representative cross section of diseases and disorders in the flock. It should be noted here that birds in all four lines were hatched, reared, and housed together so that environmental conditions cannot be held responsible for the differences between the several lines.

The avian leukosis complex (paralysis complex) includes neurolymphomatosis, visceral lymphomatosis, ocular lymphomatosis, osteopetrosis, erythroblastosis, granuloblastosis, and myelocytomatosis. The most prevalent forms of the complex were neural and visceral lymphomatosis. It will be noted that the incidence of this complex varied widely from year to year. In the generation hatched in 1935 a single case occurred in the miscellaneous group of experimental birds and in 1937 only one case was observed and this was in the control group. The generation hatched in 1938 showed a very high incidence of the complex in the miscellaneous group. The complete freedom of the high mortality line and the low incidence in the low mortality line are worthy of note. In the control group the disease showed an incidence of 17.65 percent, while in the miscellaneous group 60 percent of the birds showed evidence of the complex. In the 1939 generation, a low incidence of the avian leukosis complex was evident, and in the large control line no case was discovered. In fact, there were but two cases in the entire population. The death rate from the complex was high in 1940 and in 1941. In the last generation reported in the table the incidence was relatively high in the control line but had declined to a low level in the miscellaneous line. In the last two generations there was no evidence of the disease in either the high or the low mortality lines.

These data tend to support the idea of a cyclic behavior of the avian leukosis complex through a period of years. Both the high and the low mortality lines were so nearly free of the complex that it played a minor role in their mortality rates. There is very good evidence of a close parallelism between the incidence of the avian leukosis complex and the incidence of other diseases and disorders. In other words, in the generations where the total mortality rate was high, there was a high incidence of the complex.

Miscellaneous tumors not considered to be associated with the avian leukosis complex did not appear frequently in the different lines. Digestive disorders ranked high in importance in these young birds. Kidney disorders occurred much less frequently. Reproductive disorders and staphylococcosis were extremely unimportant. Other disorders were relatively unimportant, but cannibalism was of sporadic occurrence. The number of cases where no diagnosis was made on necropsy was significant.

The last two columns of the table set forth the number and percentage of dead birds that were examined in the laboratory. In many instances the number of birds examined was too small to give a representative sample. The fact should be noted, however, that there have been no serious outbreaks of contagious or infectious diseases in the flock aside from the avian leukosis complex.

In general, the data suggest that a generation of birds showing a high incidence of the avian leukosis complex before the age of 6 months is likely to be attacked by a large number of pathological conditions and disorders to bring the total mortality rate to a high level.

Table 2.—Distribution of Pathological Conditions and Disorders in Birds Necropsied Between the Age of Eight Weeks and Six Months.

Group and Year Hatched	Percentage of Birds with Various Diseases and Disorders											Number of Birds Examined	Percentage of Dead Birds Examined
	Avian Leukosis Complex	Miscellaneous Tumors	Digestive Disorders	Kidney Disorders	Reproductive Disorders	Staphylococcic Infections	Parasites	Injury	Miscellaneous	Cannibalism	No Diagnosis		
1935													
Control			50.0								50.0	2	16.7
High Mortality												0	
Low Mortality												0	
Miscellaneous	16.7		16.7			16.7			16.7	16.7	33.3	6	11.5
1937													
Control	14.3		28.6			14.3					42.9	7	36.8
High Mortality												0	
Low Mortality				33.3			33.3				33.3	3	75.0
Miscellaneous		22.2	11.1	11.1					22.2		33.3	9	33.3
1938													
Control	17.7			17.7			11.8	5.9	35.3	5.9	29.4	17	58.6
High Mortality											100.0	3	37.5
Low Mortality	9.1		9.1				18.2	36.4		27.3	18.2	11	44.0
Miscellaneous	60.0	2.2	8.9	6.7	2.2	2.2	4.4	2.2	8.9		15.6	45	57.0
1939													
Control			33.3	33.3					33.3			3	16.7
High Mortality	33.3		33.3								33.3	3	60.0
Low Mortality												0	
Miscellaneous	12.5		37.5				12.5	12.5	12.5		25.0	8	25.0
1940													
Control	33.3		33.3		8.3		8.3		41.7		8.3	12	41.4
High Mortality												0	
Low Mortality	80.0										20.0	5	31.3
Miscellaneous	57.9	5.3	10.5				10.5	5.3	10.5		10.5	19	40.4
1941													
Control	57.7	3.9	23.1				11.5	3.9	3.9	3.9	19.2	26	66.7
High Mortality												0	
Low Mortality												0	
Miscellaneous	66.1		16.1	5.4			12.5	7.1	3.6	1.8	10.7	56	57.1
1942													
Control	42.9		7.1				14.3		7.1	28.6	7.1	14	50.0
High Mortality			25.0				25.0			75.0		4	33.3
Low Mortality												0	
Miscellaneous	14.3	4.8	9.5				4.8	9.5	14.3	33.3	9.5	21	43.8

TABLE 3.—DISTRIBUTION OF PATHOLOGICAL CONDITIONS AND DISORDERS IN BIRDS NECROPSIED BETWEEN THE AGE OF SIX AND EIGHTEEN MONTHS.

Group and Year Hatched	Percentage of Birds with Various Diseases and Disorders											Number of Birds Examined	Percentage of Dead Birds Examined
	Avian Leukosis Complex	Miscellaneous Tumors	Digestive Disorders	Kidney Disorders	Reproductive Disorders	Staphylococcic Infections	Parasites	Injury	Miscellaneous	Cannibalism	No Diagnosis		
1935*													
Control													
Female	10.0		40.0	20.0	30.0	10.0	10.0		10.0		20.0	10	37.0
High Mortality													
Female												0	
Low Mortality													
Female												0	
Miscellaneous													
Female	21.9	3.1	12.5	12.5	25.0	9.4			18.8		15.6	32	39.0
1936*													
Control													
Female	17.7			23.5	41.2	5.9			17.7		11.8	17	94.4
High Mortality													
Female			16.7	33.3	33.3		16.7		33.3	16.7		6	100.0
Low Mortality													
Female			33.3		66.7				66.7			3	100.0
Miscellaneous													
Female	6.6	6.6	11.8	15.8	13.2	5.3	2.6	4.0	25.0	17.1	15.8	76	82.6
1937													
Control													
Male						20.0			100.0			5	35.7
Female			7.1		35.7	7.1		14.3	42.9		7.1	14	45.2
High Mortality													
Male	50.0		50.0									2	33.3
Female	33.3	33.3			66.7				33.3			3	100.0
Low Mortality													
Male												0	
Female					100.0				100.0			1	14.3
Miscellaneous													
Male			7.7			23.1		7.7	23.1	30.8	7.7	13	39.4
Female	9.1	18.2	18.2	15.2	18.2	9.1		3.0	39.4	6.1		33	42.9
1938													
Control													
Male	33.3						16.7	16.7			50.0	6	75.0
Female	52.4	4.8	4.8		19.1		9.5	4.8	14.3		4.8	21	33.3
High Mortality													
Male				100.0								1	100.0
Female	14.3		28.6		28.6			28.6	57.1		14.3	7	35.0
Low Mortality													
Male												0	
Female	50.0				50.0							2	8.7
Miscellaneous													
Male	50.0					16.7			16.7		16.7	6	22.2
Female	49.0	4.1	22.5	12.2	6.1		2.0		12.2	2.0	10.2	49	33.8

*Figures for males are not included, because the numbers involved were so few as to have no significance.

TABLE 3—Continued.

Group and Year Hatched	Percentage of Birds with Various Diseases and Disorders											Number of Birds Examined	Percentage of Dead Birds Examined
	Avian Leukosis Complex	Miscellaneous Tumors	Digestive Disorders	Kidney Disorders	Reproductive Disorders	Staphylococcic Infections	Parasites	Injury	Miscellaneous	Cannibalism	No Diagnosis		
1939													
Control													
Male		14.3		14.3					14.3	28.6	28.6	7	77.8
Female	8.6	11.4	11.4	11.4	54.3				34.3	42.9	2.9	35	59.3
High Mortality													
Male			18.2	27.3				9.1	27.3	45.5	18.2	11	47.8
Female				12.5	37.5			12.5	25.0	50.0	12.5	8	66.7
Low Mortality													
Male									66.7	33.3		3	50.0
Female				7.1	14.3			7.1	21.4	78.6		14	56.0
Miscellaneous													
Male	8.7			34.8		8.7		4.4	13.0	26.1	21.7	23	47.9
Female	8.8	10.5	10.5	21.1	28.1	1.8		1.8	26.3	50.9	7.0	57	50.0
1940													
Control													
Male				20.0		20.0			40.0	20.0		5	62.5
Female	15.4	5.1	15.4	12.8	30.8	10.3			43.6	10.3	5.1	39	60.0
High Mortality													
Male	33.3					66.7						3	33.3
Female	100.0			100.0	100.0				100.0			1	100.0
Low Mortality													
Male	11.1		22.2	16.7	5.6	16.7		5.6	16.7	5.6	22.2	18	51.4
Female		40.0	20.0	20.0					40.0			5	45.5
Miscellaneous													
Male	4.6	4.6	4.6	4.6	4.6	22.7			31.8	22.7	18.2	22	55.0
Female	22.4	5.2	15.5	13.8	12.1	1.7	3.5	8.6	13.8	12.1	15.5	58	55.8
1941													
Control													
Male			16.7	8.3		8.3		8.3	25.0	8.3	25.0	12	80.0
Female	17.9	12.5	23.2	8.9	23.2	3.6	8.9		37.5	10.7	10.7	56	68.3
High Mortality													
Male			10.0	10.0					30.0	50.0	10.0	10	58.8
Female		16.7			50.0	16.7			16.7	33.3		6	66.7
Low Mortality													
Male				25.0					12.5	50.0	25.0	8	42.1
Female			20.0	20.0	20.0					40.0		5	50.0
Miscellaneous													
Male	17.9		3.6	17.9		17.9	3.6		25.0	3.6	25.0	28	66.7
Female	17.9	4.8	17.9	19.1	22.6	2.4	6.0		29.8	11.9	7.1	84	71.2
1942													
Control													
Male						33.3			16.7	33.3	16.7	6	66.7
Female	26.9	15.4	7.7	3.9	11.5			7.7	15.4	38.5	7.7	26	56.5
High Mortality													
Male				11.4		5.7			11.4	68.6	17.1	35	72.9
Female		22.2	22.2	11.1	22.2				22.2	33.3	22.2	9	52.9
Low Mortality..													
Male	8.8		8.8	11.8		14.7		2.9	8.8	50.0	8.8	34	69.4
Female		66.7							66.7	100.0		3	60.0
Miscellaneous													
Male	3.7		11.1	7.4		33.3			29.6	11.1	18.5	27	60.0
Female	4.3	5.7	7.1	2.9	20.0	1.4	1.4	2.9	24.3	42.9	11.4	70	72.9

Necropsy Record for Males and Females from Six Months to Eighteen Months of Age

This period constitutes the first laying year in the females. The period begins with the onset of sexual maturity in both sexes and is terminated by the annual molt in both males and females. This is a part of the life span of the female that is most important from the standpoint of egg production. The data are summarized in table 3 to bring out possible sex differences and to show any changes through an 8-year period of observation.

Reference may first be made to the incidence of the avian leukosis complex during the adult period. In the generation hatched in 1935 the incidence was from 10 to 16 percent in the females. Adequate numbers of males were not submitted for necropsy. In 1936 the incidence of the complex changed little. In 1937 the complex appeared in the high mortality line for the first time. In 1938, however, there occurred a very high incidence of the complex amounting to more than 40 percent in both males and females of the control group. In the next generation the incidence in control females was 8.57 percent and there has been a rather regular increase since then up to 26.92 percent in females in 1942. This disease complex was not discovered in control males during the last four generations. The incidence of the avian leukosis complex has been rather low in both high and low mortality lines, but the numbers of birds concerned have been too small for statistical significance. In the miscellaneous group a general parallelism with the control group may be noted. Males in the miscellaneous experiments showed a higher incidence than the males of the control series. In a general way, these data point to a cyclical behavior in the incidence of the avian leukosis complex through the period of observation and is in agreement with the observation of Bostian and Dearstyne (1944).

Miscellaneous tumors not considered to be associated with the avian leukosis complex were far more numerous in females than in males. Disorders of the digestive system were a common cause of mortality during the experimental period, and were more frequent in females than in males. Kidney disorders were about as important as digestive disorders and were somewhat more prevalent in females. Reproductive disorders were confined to the females where they represent a major cause of death. Staphylococcic infections have been of rather frequent occurrence in the flock, and more prevalent in males than in females. Such infections probably gain entrance to the body through wounds. One common type of this disease is bumble foot. Parasites have not been prominent in the flock, probably because of range rotation and because sanitary measures are used to protect the birds. Losses from injury were small and have been largely controlled by careful management. Respiratory diseases have been of little consequence in the flock and are therefore grouped with the miscellaneous disorders, which include all not listed in the table. These miscellaneous disorders have affected a significant percentage of birds. Cannibalism is a common vice in flocks bred for high egg production and is greatly modified by environment. The actual eating of blood and flesh is much less common in males than in females. Numerous males are lost from fighting and these have been included under cannibalism for lack of a better classification. In the later years of the experiment the apparent increase in cannibalism is probably due to a greater percentage of such birds being sent in for necropsy.

As already indicated and as pointed out by Bostian and Dearstyne (1944), necropsy records fail to reveal the cause of death in a very significant proportion of dead birds. The birds on which no diagnosis was made on necropsy ranged from none to 50 percent among the different groups, indicating that many of the birds must have died of functional disturbances that left no significant gross evidence.

The percentages of dead birds examined during the period were variable. It is believed, however, that the records give a reasonable approximation of the incidence of diseases and disorders that were present. One fact that stands out is that when the avian leukosis complex is present there is likely to be a relatively high incidence of other diseases and disorders and consequently a high total mortality.

Relation of the Avian Leukosis Complex to Total Mortality in Females

All of the data on the incidence of the various diseases and disorders in the flock from 1937 to 1942 have been based on that part of the flock that was sent in for necropsy. These data have shown the relative importance of the different diseases and disorders in the flock, but not the relation of any particular disease to the total mortality rate.

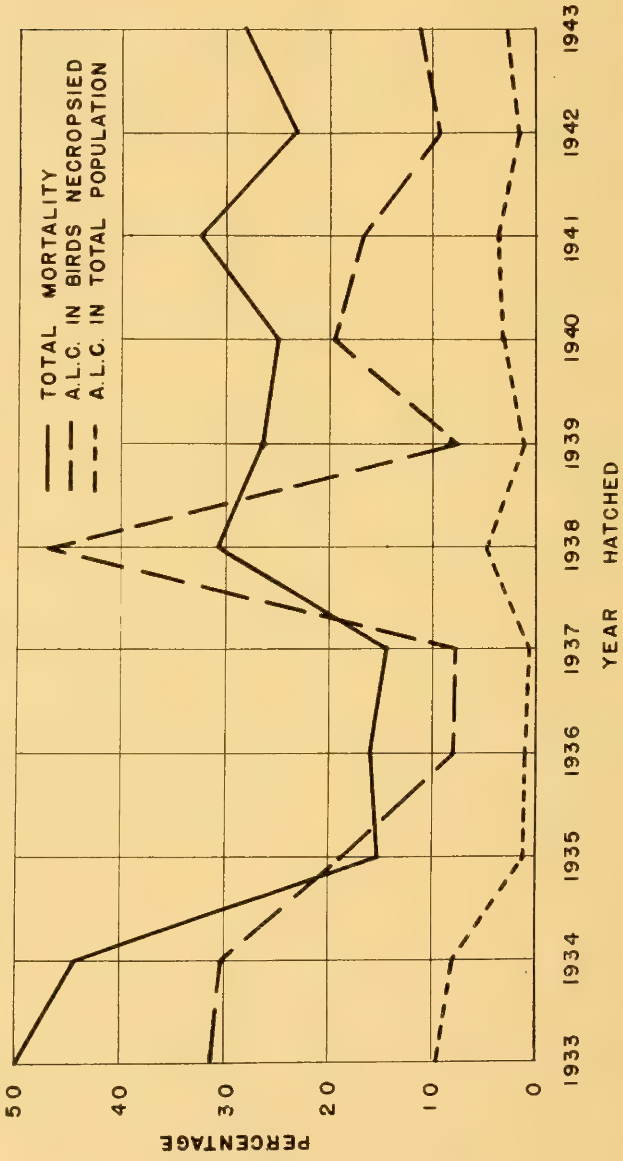
Chart 4 is therefore presented to give this information for the avian leukosis complex. The chart shows total mortality from all causes for females for one full laying year (6 to 18 months of age), the percentage of birds examined and the percentage of the total population which exhibited the avian leukosis complex over an eleven-year period. Birds developing the leukosis complex before being placed in the laying house are not included. The average number of pullets housed each year was 732.

The flock as a whole did not show a high incidence of the avian leukosis complex. The maximum incidence was 9 percent in 1933, with an average of 3.40 percent for the eleven-year period from 1933 to 1943. For the period 1937 to 1942, included in the previous sections, the mortality rate from the avian leukosis complex was 2.40 percent. Total mortality over the period was highly variable.

There is some evidence to indicate that when the leukosis complex was at a high level in the birds necropsied, there was generally a high total mortality in the flock. The data also suggest that periods of from three to five years may intervene between generations showing a high incidence of the complex. There is no evidence that the avian leukosis complex is increasing in importance in this flock.

CHART 4

TOTAL MORTALITY IN FEMALES DURING THE FIRST LAYING YEAR AND INCIDENCE OF AVIAN LEUKOSIS COMPLEX IN BIRDS NECROPSIED AND IN THE TOTAL POPULATION



SUMMARY

Records on mortality were secured over an eight-year period on 22,175 chicks up to the age of 8 weeks; on 5,067 males and 9,526 females between the ages of 8 weeks and 6 months; and on 1,132 males and 5,803 females between the ages of 6 and 18 months. Available morbid and dead birds were examined by pathologists. The following deductions seem to be warranted:

1. Selective breeding was not effective in reducing the mortality rate between hatching time and the age of 8 weeks, as shown by the insignificant differences between the lines.
2. There was a significant increase in mortality rates between the ages of 8 weeks and 6 months in the control, the high mortality, and the miscellaneous lines. The low mortality line showed no significant decline during the same period, but there was no increase in mortality rate in this line.
3. Selective breeding was not decidedly effective in reducing mortality from all causes in males and females between the ages of 6 and 18 months. The control line showed no significant change during the period of observation. The rate of change in both the high and the low mortality lines was insignificant. The miscellaneous group was the only one to show a significant increase in mortality rate.
4. Necropsy records demonstrated that the avian leukosis complex showed a cyclic behavior in the eight-year period, and indicate that when the avian leukosis complex appeared in a generation, it was likely to be accompanied by a high incidence of other diseases and disorders.
5. Digestive disorders appeared prominently in birds examined.
6. Miscellaneous diseases and disorders, including respiratory diseases, were not prominent in the flock.
7. Cannibalism was variable and generally more destructive in males than in females, when males that died from fighting are included.

REFERENCES

Asmundson, V. S., and Jacob Biely. 1932. Inheritance of resistance to fowl paralysis. 1. Differences in susceptibility. Canad. Jour. Res. 6:171-176.

Bearse, G. R., and C. F. McClary. 1939. The results of eight years' selection for disease resistance and susceptibility in White Leghorns. Rpt. 31st Ann. Meeting, Poultry Sci. Assoc. p. 1.

Biely, Jacob, Elvira Palmer, and V. S. Asmundson. 1932. II. On a significant difference in the incidence of fowl paralysis in two groups of chicks. Canad. Jour. Res. 6:374-380.

Bostian, C. H., and R. S. Dearstyne. 1944. The influence of breeding on the livability of poultry. N. C. Agr. Expt. Sta. Tech. Bul. 79.

Bryant, R. L., and E. P. Johnson. 1944. Incidence of mortality in two strains of Single Comb White Leghorn chickens. Poultry Sci. 23 (6):521-524.

DeOme, K. B. 1943. Intraperitoneal injection of lymphomatous nerve tissue into resistant and susceptible chickens. Poultry Sci. 22 (5):381-394.

Frateur, J. L. 1924. The hereditary resistance of the fowl to the bacillus of diphtheria. Proc. Second World's Poultry Cong. Part 2, pp. 68-71.

Gowen, J. W., and M. L. Calhoun. 1943. Factors affecting genetic resistance of mice to mouse typhoid. Jour. Infect. Dis. 73:40-56.

Hetzer, H. O. 1937. The genetic basis for resistance and susceptibility to Salmonella aertrycke in mice. Genetics 22:264-283.

Hutt, F. B., R. K. Cole, and J. H. Bruckner. 1941. Four generations of fowls bred for resistance to neoplasms. Poultry Sci. 20 (6):514-526.

Jeffrey, F. P., F. R. Beaudette, and C. B. Hudson. 1942. The role of breeding in the control of fowl paralysis. N. J. Agr. Expt. Sta. Bul. 696.

Lambert, W. V. 1932. Natural resistance to disease in the chicken. Jour. Immun. 23 (3):229-260.

Lee, C. D., and H. L. Wilcke. 1941. Transmission experiments with iritis of fowls. Amer. Jour. Vet. Res. 2:292-294.

Marble, D. R. 1939. Breeding poultry for viability. Pa. Agr. Expt. Sta. Bul. 377.

McClary, C. F., and C. W. Upp. 1939. Is paralysis of fowls as manifested by iritis transmitted through the egg? Poultry Sci. 18 (3):210-219.

Nelson, N. M., and Frank Thorp, Jr. 1943. Ocular lymphomatosis with special reference to chromatism of the irides. Amer. Jour. Vet. Res. 4 (12):294-304.

Pearl, Raymond. 1940. Medical biometry and statistics. W. B. Saunders Co., Philadelphia, Pa. pp. 456-457.

Roberts, E., and L. E. Card. 1935. Inheritance of resistance to bacterial infection in animals. Ill. Agr. Expt. Sta. Bul. 419.

Sturkie, P. D. 1943. Five years of selection for viability in White Leghorn chickens. Poultry Sci. 22 (2):155-160.

Taylor, L. W., I. M. Lerner, K. B. DeOme, and J. R. Beach. 1943. Eight years of progeny test selection for resistance and susceptibility to lymphomatosis. Poultry Sci. 22 (5):339-347.

Waters, N. F., and C. O. Prickett. 1944. The development of families of chickens free of lymphomatosis. Poultry Sci. 23 (4):321-333.

Winton, Berley. 1943. Fourth Annual Report of the Regional Poultry Research Laboratory, East Lansing, Mich.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
4m (b) 12-44-15376

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

JUN 7 1945

BULLETIN NO. 421 NOVEMBER 1944

The Identification of Pear Varieties From Non-Bearing Trees

By Lawrence Southwick, A. P. French, and O. C. Roberts

The identification of varieties before fruit trees leave the nursery is important if disappointments in the orchard are to be avoided. This bulletin considers the characteristics by which nursery pear trees may be identified and records descriptions of 47 varieties and photographs of 41 varieties.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

INDEX TO PAGE REFERENCES

Variety	Prominent Characteristics and Shoot Illustrations	Other Illustrations	Variety Comparisons	Descriptions	Other Mention
Anjou	18, 19	8, 13		44	9, 12, 16
Bantam	18, 19	6, 12, 16		44	4, 5, 9, 10, 12, 16, 17
Bartlett	18, 19	7, 8, 11 12, 13, 16	34, 35, 37, 39 40	44	5, 9, 10, 12, 16
Bierschmidt				44	17
Bosc	18, 19	7, 8	37, 40	44	4, 5, 9, 12, 17
Campas					48 (footnote)
Cayuga	18, 19		34	44	9, 12
Caywood	20, 21	10	34	44	9, 16
Clairgeau	20, 21	15		45	9, 10, 13, 16
Clapp Favorite	20, 21	6, 12, 15	34	45	5, 9, 12, 16
Clyde	20, 21	16	35	45	16
Comice	20, 21		35	45	5, 9, 12, 16
Conference	22, 23		36	45	
Cope's Seedless	22, 23		35	45	17
Covert	22, 23		36	46	9, 17
Dana Hovey	22, 23	11, 15		46	5, 9, 10, 16
Douglas	22, 23		36	46	9, 12, 16
Duchess	24, 25		36	46	9, 12
Dumont	24, 25		36	46	12, 16
Early Seckel	24, 25		37	46	5
Elizabeth				46	17
Endicott				47	17
Ewart	24, 25	5	37	47	4
"False Bosc"	24, 25	14, 15	37	47	9, 13
Flemish Beauty	26, 27	7, 12, 14	34, 39	47	5, 9, 12, 13
Garber	26, 27	7, 14	38	47	5, 9, 10, 13
Gorham	26, 27	11, 12	38	47	5, 9, 10, 12, 16
Hardy				48	17
Howell				48	17
Kieffer	26, 27	10, 14	38	48	9, 12, 13
Koonce	26, 27	15		48	10, 12, 13
Lawrence	28, 29	6	38	48	5, 16
Lincoln	28, 29	13	39	48	12, 13 16
Lincoln Coreless				49	17
Louise	28, 29			49	16
Ovid	28, 29	11, 16		49	9, 10, 13, 16, 17
Parker	28, 29		39	49	
Patten	30, 31			49	10, 16
Phelps	30, 31		39	49	
Pulteney	30, 31		38, 40	49	9
Seckel	30, 31	10, 11	35, 37, 40	50	5, 9, 10, 13
Sheldon	30, 31	12, 16	34, 35, 38, 39	50	9, 12, 16
Variety Key					42, 43
Vermont Beauty	32, 33	5		50	5, 9
Waite	32, 33			50	9
Wilder	32, 33	5, 11		50	4, 9, 10, 16
Willard	32, 33	10, 12, 15	36, 40	50	9, 12, 13, 16, 17
Winter Nelis	32, 33			51	4
Worden Seckel	32, 33		40	51	5, 16

THE IDENTIFICATION OF PEAR VARIETIES FROM NON-BEARING TREES

By Lawrence Southwick, Research Assistant in Pomology,
A. P. French, Professor of Pomology, and
O. C. Roberts, Assistant Professor of Pomology[1]

This bulletin is the sixth in a series on the nursery identification of fruit varieties. Bulletins relating to apples, cherries, and plums have been published (1, 3, 4, 5, 7).

It is the purpose of this bulletin to acquaint the reader with the characteristics of young, non-bearing pear trees which are utilized in the identification of varieties. Identification of pear varieties in the nursery row is just as feasible and positive as identification in the bearing orchard. In the one case, plant characters are used; in the other, mainly the fruit itself. The important advantage of the first method is that variety mixtures, which occur for one reason or another more or less frequently in commercial nurseries, can be detected and corrected before the trees are dug. Annual inspection of fruit nursery stock for trueness-to-name by men trained in variety identification is now a recognized nursery practice.

Although it is probably true that other tree fruits have been mixed in commercial nurseries rather more generally and seriously than pears; yet in the experience of the authors, mixtures in pears are not infrequent, particularly among some of the newer introductions. Over a period of years, many mixtures have likewise been found among the old standard varieties. Hence, the need is apparent for information which may help to eliminate such mixtures.

This bulletin records in words and pictures much of the information necessary to distinguish pear varieties from one another. The list of varieties includes a majority of the pears now found in commercial nurseries as well as some less common old varieties and a number of the newer ones. The descriptions and illustrations were derived largely from one-year and two-year budded trees growing in the Experiment Station nurseries at Amherst. Every effort was made to establish the identity of each variety. The sources of budwood include the Minnesota Agricultural Experiment Station at St. Paul, the New York State Agricultural Experiment Station at Geneva, the Ohio Agricultural Experiment Station at Wooster, the Ontario Horticultural Experiment Station at Vineland (Canada), and our own bearing trees at Amherst.

Previous publications dealing with varietal differences of pear varieties as nursery trees are few. Upshall (8) has briefly described some of the more important old varieties, and Shoemaker (6) has made some brief comments concerning certain characteristics useful in pear variety identification. Hedrick's (2) descriptions of pear trees were made from bearing trees which cannot be relied upon to portray accurately and completely the various character differences which are found in vigorous nursery trees.

It should be stressed here that, as with other tree fruits, the characteristics of nursery pear trees cannot be learned satisfactorily from printed descriptions or illustrations alone. Much time must be spent in close observation of nursery trees that are known to be true-to-name before one can positively identify varieties and accurately separate mixtures in the nursery row.

---

[1] The writers are indebted to Dr. J. K. Shaw for valuable counsel both in the field work and in the preparation of the manuscript and to R. L. Coffin for the photographic work.

Inspection of Nursery Trees for Trueness-to-Name

It is the prevailing practice to inspect nursery trees for trueness-to-name in midsummer. Experience has shown that, in general, varietal differences are most apparent in trees that are in active growth. When growth slows down as a result of drought, lack of nutrients, insect or disease attacks, or cool fall weather, some of the useful distinguishing characteristics often become less apparent or disappear altogether. However, there is no one time when all of the plant characters used in variety identification are most obvious or valuable. It is often a good plan to study trees throughout the growing season in order to observe the degrees of variation in the prominence of the various distinguishing characteristics.

Nursery trees have been examined successfully for trueness-to-name throughout the period from June to October, which demonstrates that inspection can be done almost anytime during the growing season. However, since early-season inspection gives opportunity to detect mixtures before budwood is taken for propagation and since the small size of the trees at this time and the relative freedom from insect, disease, and other damage facilitate rapid inspection, the writers and their colleagues have in recent years examined fruit tree nursery stock for trueness-to-name during the month of July so far as possible.

It is true that nursery trees often vary in appearance when growing in widely separated localities. Nevertheless, experience has shown that when a plant character is altered by environment, the several varieties usually maintain their relative order for that character. Hence, the identification of varieties in the nursery row is feasible no matter where they are grown so long as the trees are making good growth. Insect and disease damage on the one hand and spray or dust deposits on the other may sometimes increase the difficulty of positive variety identification, but only rarely have these factors obscured all distinguishing characteristics.

How Pear Varieties Differ

There are many plant characters of importance in distinguishing one pear variety from another. Sometimes a single character is sufficient for positive identification of a variety; more often several characters are considered. Those found by actual experience to be most useful are briefly described. The accompanying pictures (Figures 1-12) show specimens which illustrate some of the more important distinguishing characters. It should be emphasized that, since we are dealing with living plants, the character in question will not usually be equally prominent in all individuals or in all portions of a single tree. Yet these are characters by which varieties of pears may be distinguished.

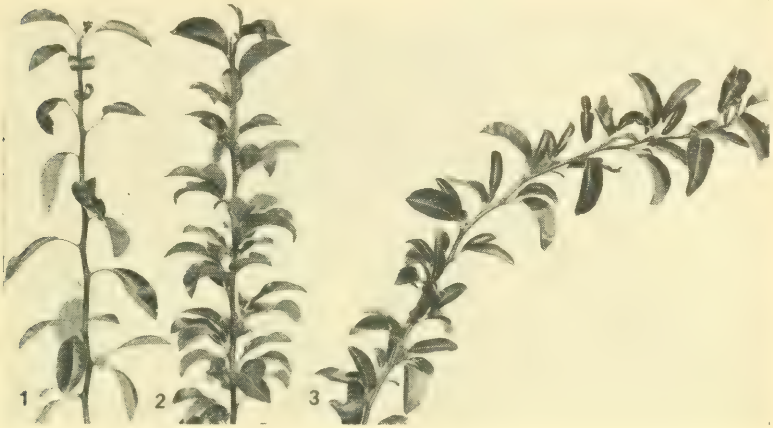
TREE CHARACTERS

The *habit of growth* usually refers to the position and length of individual shoots on two-year trees. Usually, the term upright-spreading fairly well describes the growth habit of pear varieties. Occasionally, it may be spreading as in Winter Nelis or even spreading to drooping as in Bantam. On the other hand, it may be essentially upright as in Wilder. Some varieties are typically crooked growers and often require staking to produce salable trees. Bosc and Ewart are apt to be more crooked than most varieties (Figure 1).

The vigor of a single variety varies widely in different soils, localities, and seasons. However, after this fact has been taken into consideration, it is still evident that comparative *tree height* is an important varietal characteristic.

For example, Early Seckel usually does not grow so tall as Seckel, nor Seckel so tall as Worden Seckel. Often a difference in the average stature of trees in a nursery row is the first indication of a varietal mixture.

Some varieties such as Gorham are inclined to be more *branchy* than others even as one-year trees (whips). Many varieties usually grow few lateral or side branches until the second year following budding unless such growths are forced because of some injury to the terminal by insect damage, accidental breakage, or summer pruning. The degree of lateral branching the first year from the bud varies from year to year with a single variety, depending, probably, on environmental conditions.



Figue 1. Type of Growth.

1. **VERMONT BEAUTY — Not leafy**
2. **WILDER — Leafy**
3. **EWART — Crooked grower**

Certain *shoot characteristics* are important (Figure 2.) The *diameter or stoutness* of shoots may be a valuable identifying character. Shoots vary from stout as in Clapp Favorite to slender as in Bantam. The *degree of zigzag*, or alternate change in direction of growth at the nodes, is of some significance. Shoots may be straight as in Lawrence to distinctly zigzag as in Bantam. The length of the *internodes*, spaces between buds along shoots, may vary from short as in Lawrence to rather long as in Bantam.

The *lenticels* on shoots are particularly valuable. With different varieties, lenticels vary in number, size, prominence (whether flush or raised), shape, color, and conspicuousness (Figure 3). They may vary from very numerous as in Garber, through medium in number as in many varieties, to rather few as in Gorham; from large as in Bosc to small as in Flemish Beauty; from flush as in Flemish Beauty to raised (rough to the touch) as in Bosc; from usually round as in Comice to often elongated as in Clapp Favorite; from russet colored as in many varieties such as Bartlett to white as in Garber; and from inconspicuous as in Comice and Bartlett to very conspicuous as in Bosc and Garber. With some varieties, the lenticels are very distinct in outline as in Vermont Beauty; in others they are rather indistinct in outline as in Dana Hovey. It should be borne in mind that with almost all varieties the shoot lenticels are more elongated and smaller near

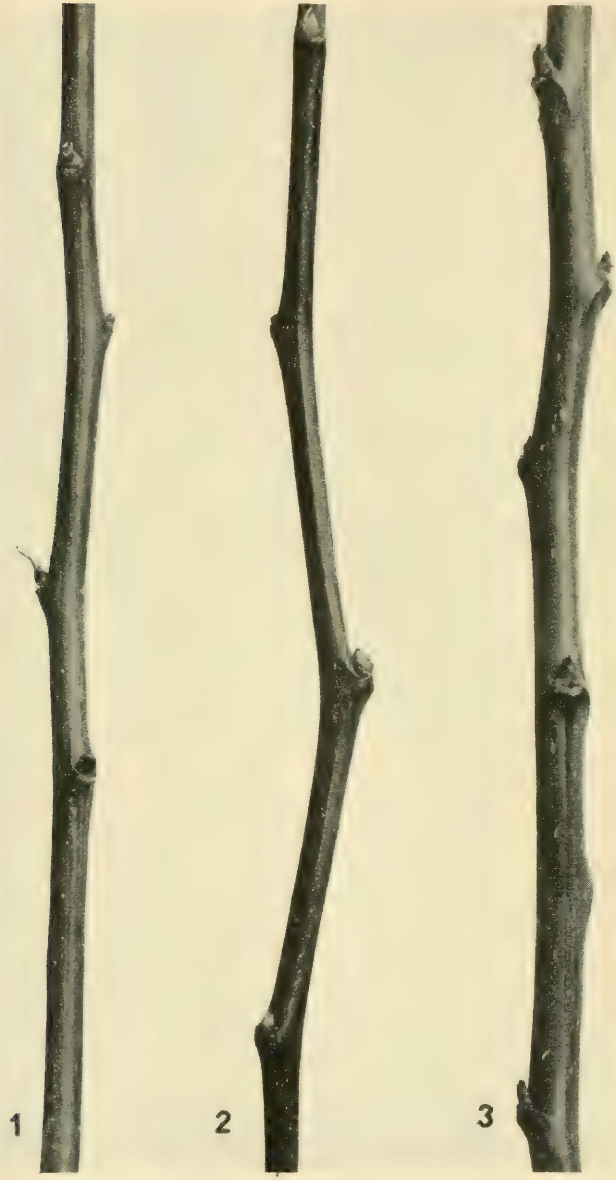


Figure 2. Shoots.

1. **LAWRENCE** — Moderately slender, straight, short internodes
2. **BANTAM** — Slender, zigzag, long internodes
3. **CLAPP FAVORITE** — Stout, straight

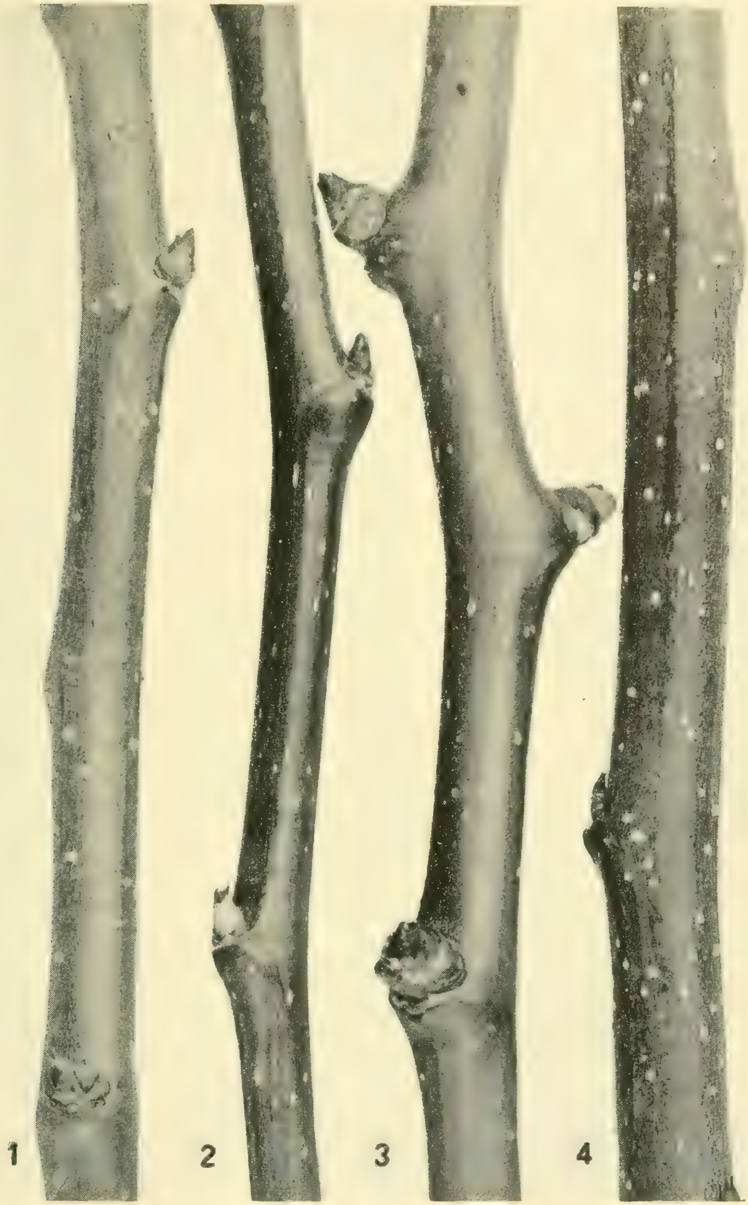


Figure 3. Lenticels. (2×)

1. BOSC — Large, numerous, distinctly raised, conspicuous
2. FLEMISH BEAUTY — Small, flush, moderately few
3. BARTLETT — Russet, inconspicuous
4. GARBER — White, very numerous, very conspicuous

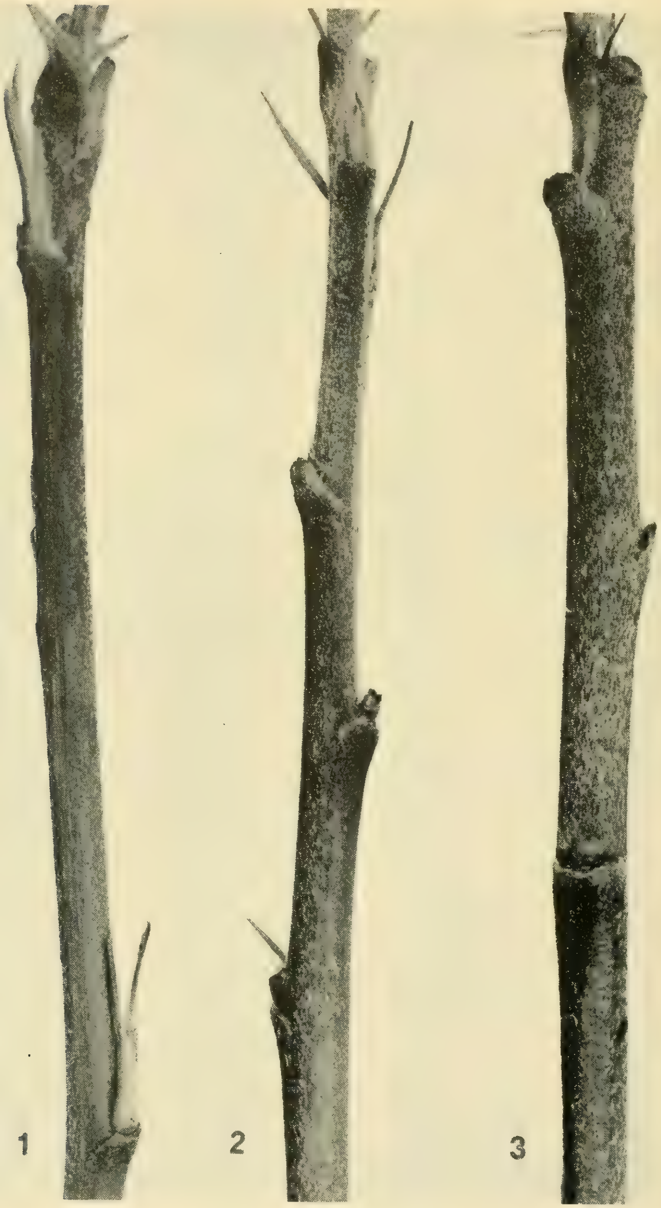


Figure 4. Shoot Pubescence. (2×)

1. **BOSC** — Light
2. **BARTLETT** — Medium
3. **ANJOU** — Heavy

the growing tip. Usually the important lenticel characteristics can be seen to the best advantage somewhat back from the tip of the shoot.

The *shoot pubescence* is often a valuable character in the identification of pear varieties. It may vary from light as in Bosc through medium as in Bartlett to heavy as in Anjou (Figure 4). Occasionally it is very light as in Bantam. Pubescence is usually whitish but in two varieties, Kieffer and Garber, it is a rusty brown color. With Douglas, it usually is orange colored near the terminal bud but whitish elsewhere.

The *bark color* may be of value in both one-year and two-year trees. The color of *two-year trunk bark* is usually a mixture of greens, yellows, and browns. A few examples are: Covert, grayish green; Willard, greenish brown; Bartlett, medium yellowish brown; Sheldon, light to medium brown; Cayuga, medium brown; Seckel, rather dark brown; Clapp Favorite, reddish brown; Bantam, dark grayish brown; Caywood, purplish brown. The color of *one-year bark* generally contains more green and red but less yellow and brown than that of two-year bark. Examples are: Dana Hovey, green to brownish green; Comice, prevailingly green to dull brown; Douglas, brown; Flemish Beauty, reddish brown; Clapp Favorite, red. The typical one-year bark color is usually found on the lower half of the growing shoot.

The *color of the young shoots* near the shoot tips is often worthy of note and is frequently green, pink, reddish tinged, or reddish.

LEAF CHARACTERS

The *color of the growing tip* or the small young unfolding leaves at the tip of a shoot is often a very valuable variety character, especially since differences often become evident very early in the growing season. As the season progresses, the tips in general are apt to take on somewhat more reddish coloration, but still maintain their relative order for this character. A few examples of growing-tip color are: Dana Hovey, green; Clairgeau, slightly reddish tinged; Anjou, pinkish tinged; Bosc, reddish tinged; Pulteney, reddish; Douglas, red.

The *petiole* or leaf stem is of some importance. The angle that the petiole makes with an upright shoot is usually about 45° or halfway between horizontal and vertical. Such a petiole is called medium-angled. However, in some varieties the petioles are wide-angled as in Ovid, or occasionally narrow-angled as in "False Bosc." Petioles vary in length, thickness, and color. They may be short and thick as in Waite, long and moderately slender as in Vermont Beauty, short and slender as in Gorham, or long and slender as in Bantam. The color of petioles varies from green as in Bantam through reddish tinged as in Anjou to reddish as in Douglas.

The "*leafiness*" of pear shoots varies with variety. Some varieties like Wilder are more "leafy" than average. With others, like Vermont Beauty, the foliage is rather sparse (Figure 1).

The *size of the leaf blade* is often influenced materially by the vigor of growth of a tree. Nevertheless, differences in leaf size are quite dependable between varieties. Average size of the blade varies from small as in Bantam to large as in Garber. With most varieties, the basal shoot leaves are usually somewhat larger than the others and the younger leaves near the shoot tips are smaller than average. However, with a few varieties like Duchess and Douglas, large leaf size is often characteristic of all leaves even to the tip of a shoot, particularly after the terminal bud has formed and length growth has ceased.

Leaf shape is often roundish oval as in Seckel, oval as in Kieffer, ovate as in Willard, or elliptic as in Caywood (Figure 5). The leaves normally described are those in the middle portion of a one-year shoot growth, although all leaves are more or less taken into consideration when determining the leaf shape of any variety, because leaf shape may be variable from one part of a tree to another. Frequently, leaves are described as roundish-oval, long-oval, oval to elliptic, etc., to allow for normal shape variation.

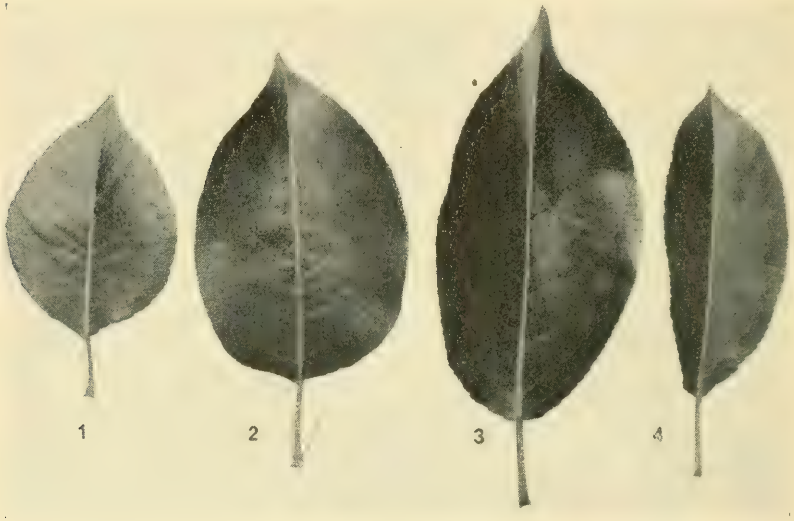


Figure 5. Leaf Shape

1. **SECKEL** — Roundish oval
2. **WILLARD** — Ovate
3. **KIEFFER** — Oval
4. **CAYWOOD** — Elliptic

The leaves of most pear varieties show some degree of *folding*, but the amount and type of folding differs with the variety (Figure 6). With some pears, the majority of leaves are usually flat with some very slight folding as in Garber or Clairgeau. Broad U-folding as in Ovid is rather common; medium U-folding as in Bartlett is somewhat less common; and narrow U-folding as in Bantam or sometimes in Bartlett is rather infrequently found in pears. With some varieties, the upward folding of the leaf is often V-shaped although the difference between U-folding and V-folding is sometimes not uniformly distinct. V-folding may be broad as in Wilder to medium or sometimes narrow as in Dana Hovey. Other variations in leaf folding are occasionally found. Thus, many leaves of Gorham are typically saucer-folded and those of Seckel or Koonce are often somewhat reverse saucer-folded with the leaf edges turned downward instead of upward. As with leaf shape, the degree of leaf folding is usually not uniform throughout a nursery tree. For example, the leaves of Patten are usually folded broadly; but the young shoot leaves of that variety may be narrow U-folded. With Dana Hovey, the lower leaves may be broad V-folded while those nearer the shoot tip are narrow V-folded. It has been the experience of the writers that leaf-folding is a very useful character in variety identification. However, since such a character is somewhat variable and may be influenced by environmental conditions, considerable experience is necessary before one can be certain how much dependence to place on it at any particular time or place.

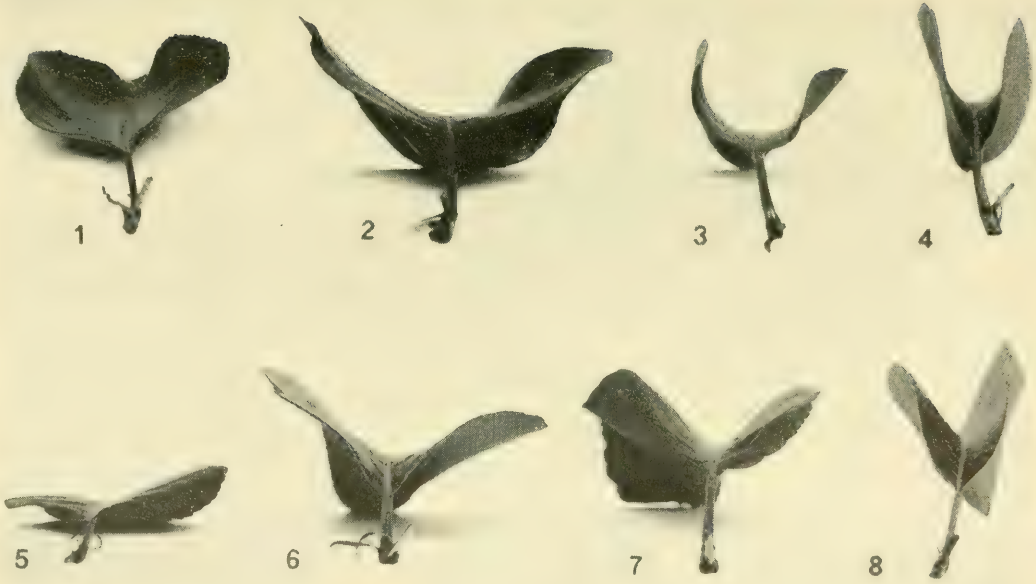


Figure 6. Leaf Folding.

1. GORHAM Saucer-folded
2. OVID — Broad U-folded
3. BARTLETT — Medium U-folded
4. BARTLETT — Narrow U-folded
5. SECKEL — Reverse saucer-folded
6. WILDER — Broad V-folded
7. DANA HOVEY – Medium V-folded
8. DANA HOVEY — Narrow V-folded

Leaf reflexion — the backward curvature of the petiole and midrib — is sometimes an important distinguishing varietal character. This may be moderate as in Duchess, considerable as in Comice, or pronounced as in Dumont. With certain varieties the leaf curvature is uniform throughout the length of the petiole and midrib as in Douglas; in others as Anjou the leaves are reflexed principally at the base of the blade. Frequently, there is practically no pronounced reflexion as in Bartlett. In Kieffer, the lack of reflexion results in a very upright leaf position. Occasionally, pronounced reflexion at the blade base plus a wide petiole angle give leaves the appearance of drooping, as in Anjou, for example. These characteristics can be seen in the illustrations of one-year shoots in a following section.

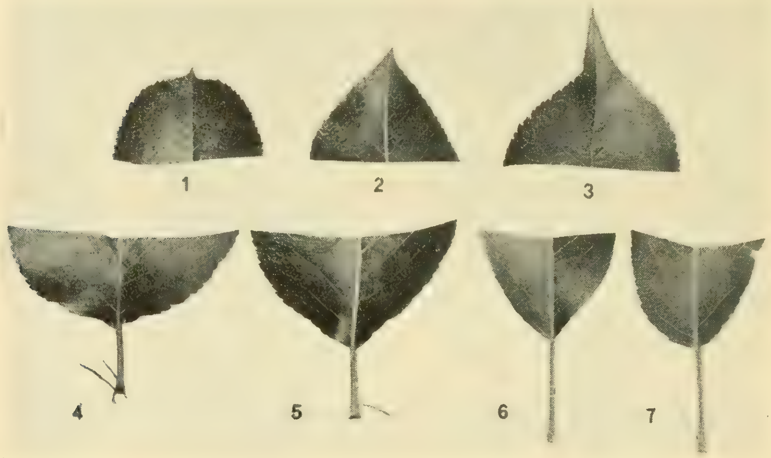


Figure 7. Leaf Apex and Base.

1. **GORHAM — Full apex, mucronate tip**
2. **BARTLETT — Moderately full apex, acute tip**
3. **BANTAM — Long acuminate tip**

4. **WILLARD — Full base**
5. **CLAPP FAVORITE — Moderately full base**
6. **FLEMISH BEAUTY — Moderately narrow base**
7. **SHELDON — Moderately narrow rounded base**

The *leaf base* may be described as full as in Willard, moderately full as in Clapp Favorite, or rather narrow as in Flemish Beauty (Figure 7). The base of Sheldon leaves is often rather narrow and distinctly rounded.

The *leaf apex* occasionally may be full as in Gorham, or moderately narrow as in Cayuga; however, it is usually moderately full as in Bartlett. The *leaf tip* may be mucronate as in Gorham, acute as in Bartlett, or acuminate as in Bantam (Figure 7).

The type and amount of *waving of the leaf margin* vary considerably with variety (Figure 8). The leaf margin in pears is often coarsely waved as in Koonce or Bosc, while occasionally as in Lincoln the waving is less coarse. The amount of waving varies from none to moderate. When the margin is not waved, as in Bartlett for example, it is called even. The coarse margin waving of Anjou is largely caused by the characteristic crookedness of the midrib.

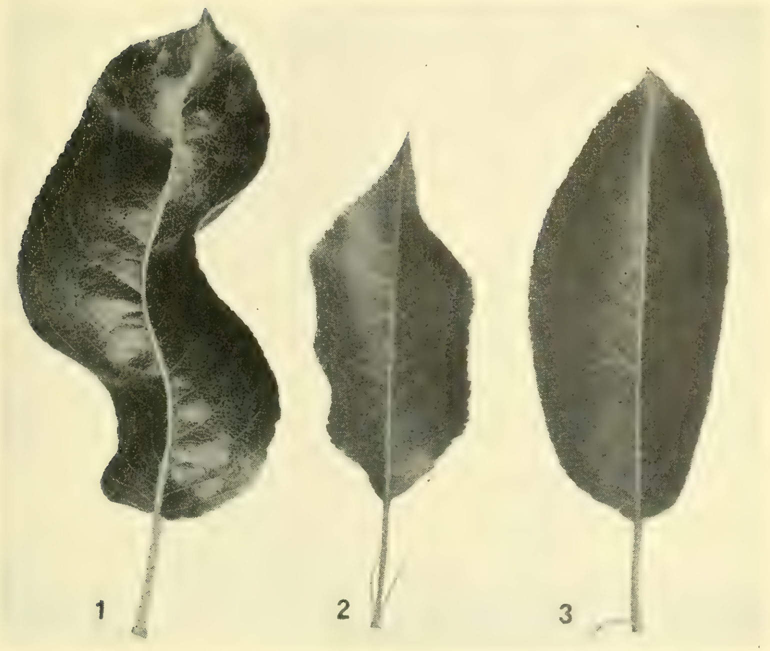


Figure 8. Leaf Margin.

1. **ANJOU — Crooked midrib and coarse waving of margin**
2. **LINCOLN — Medium to coarsely waved**
3. **BARTLETT — Even**

The *nature of the upper surface* of the leaf is worthy of attention in identification work. Although in the majority of pear varieties the leaf surface is smooth as in Flemish Beauty; in a few, it is more or less distinctly and usually very finely bullate (pebbled or blistered) as in "False Bosc" (Figure 9). Also, the leaves of a few varieties are slightly rugose (wrinkled or uneven) as in Seckel. The rugoseness is sometimes confined to the section along the midrib as in Garber (Figure 9). Sometimes a variety has essentially smooth-surfaced leaves with occasional large, shallow depressions as in Clairgeau or Ovid. In some varieties, as Lincoln, the principal veins are numerous. In Willard they are distinctly raised, while in Koonce they are depressed (Figure 10). In a few cases, as in Kieffer, the net veins are uniformly depressed (Figure 9). A further characteristic of the upper leaf surface concerns the presence or absence of pubescence. In most pear varieties the leaves are not pubescent, but in some, there is more or less pubescence as in "False Bosc" (Figure 10) or Koonce.

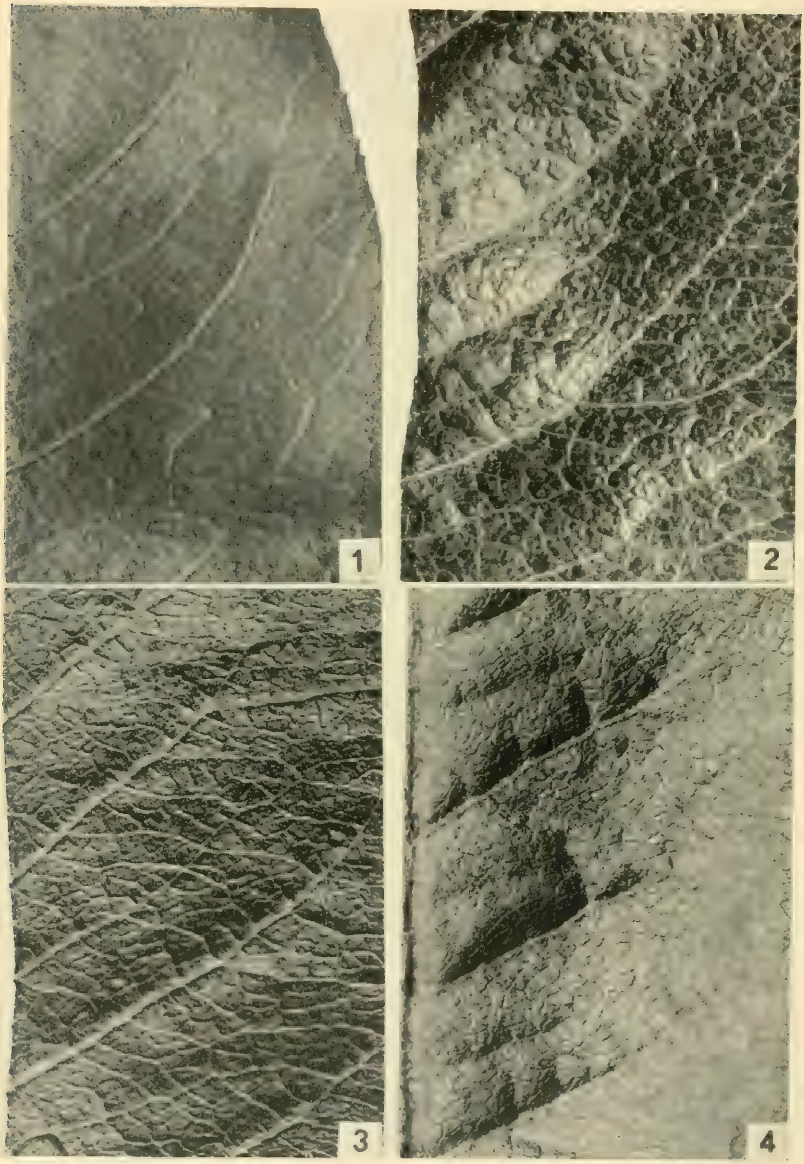


Figure 9. Leaf Surface. (3×)

1. **FLEMISH BEAUTY** — Smooth
2. **"FALSE BOSC"** — Very finely bullate
3. **KIEFFER** — Net veins uniformly depressed
4. **GARBER** — Rugose along midrib

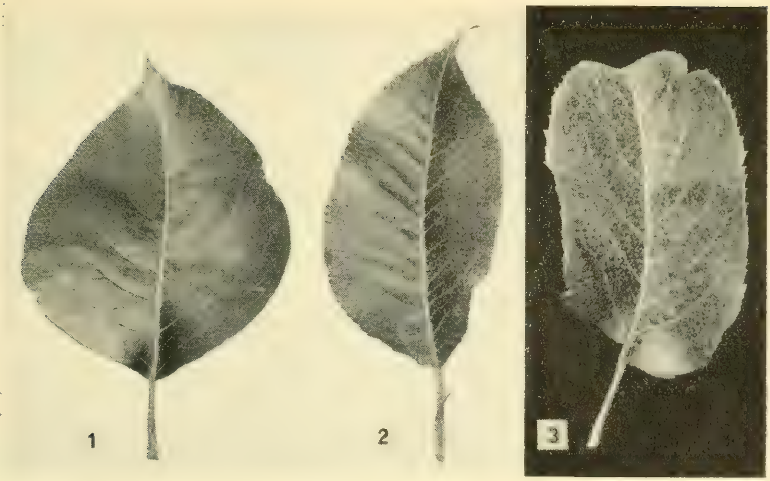


Figure 10. Leaf Surface

1. **WILLARD — Raised lateral veins**
2. **KOONCE — Depressed lateral veins**
3. **"FALSE BOSC" — Pubescent upper surface**

The amount or degree of *light reflection* from leaves depends not only on variety but also on leaf age, time of observation during the growing season, amount of dust on the leaf surface, and brightness of the day. Despite these and other variables, light reflection is usually a fairly valuable distinctive character. Leaves

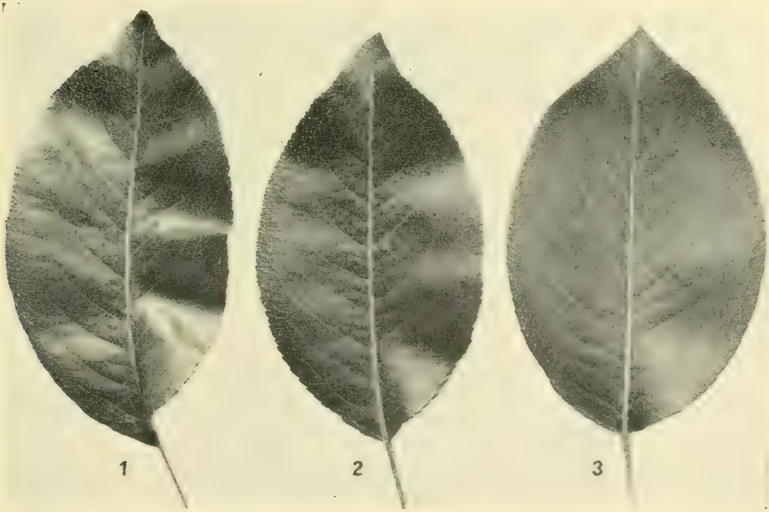


Figure 11. Light Reflection

1. **DANA HOVEY — Very glossy**
2. **CLAPP FAVORITE — Semi-glossy**
3. **CLAIRGEAU — Dull**

can be described as dull as in Clairgeau, semi-glossy as in Clapp Favorite, or glossy as in Dana Hovey (Figure 11). Of course, there are intermediates between these three conditions. Also, the glossiness of the different leaves on one variety may vary. For example, Ovid leaves are described as semi-glossy to moderately dull, and those of Comice as semi-glossy to dull.

The value of *leaf color* in variety identification is considerable, despite the fact that amount and shade of color may be moderately to greatly influenced by nutritional conditions. It is common knowledge, for instance, that the foliage of well-fertilized nursery trees is a deeper green than that of trees growing on poor soil, lacking in nitrogen. Nevertheless, the general leaf color is one of the first characteristics to be taken into consideration when examining nursery trees for trueness-to-name. An abrupt color change in a nursery row may often indicate a change of variety. For example, the average color of well-developed leaves on vigorous shoots may be rather light green as in Wilder, medium green as in Caywood, dark green as in Willard, light yellowish green as in Sheldon, medium yellowish green as in Anjou, dark yellowish green as in Bartlett, or mottled light yellowish green as in Worden Seckel. The development of reddish coloration in late summer and fall varies with variety. Douglas leaves often turn red earlier and more uniformly than those of other varieties. Louise, Comice, Dumont and a few others also tend to develop more or less red in their foliage. On the other hand, Gorham and Lincoln foliage usually remains green until cold weather. Other varieties remaining mostly green include Lawrence and Patten.

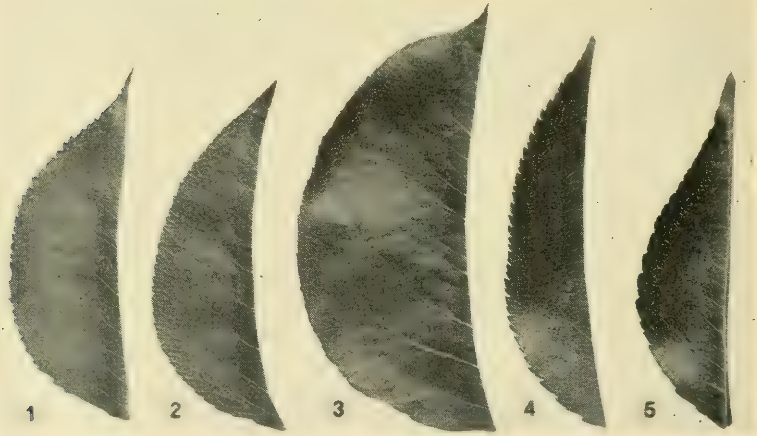


Figure 12. Serrations.

1. BANTAM — Moderately fine, setose serrate, moderately regular, distinct, prominent
2. BARTLETT — Fine, serrate, moderately shallow, regular
3. OVID — Moderately coarse, very shallow, irregular, often indistinct
4. SHELDON — Rather deep, serrate, slightly hooked, regular, prominent
5. CLYDE — Coarse, dull serrate, slightly hooked, rather irregular

The *leaf serrations* or teeth along the leaf margins are worth noting (Figure 12). Serrations may vary from fine as in Bartlett to coarse as in Ovid; very shallow as in Ovid to rather deep as in Sheldon; dull serrate as in Clyde to very sharply or setose serrate as in Bantam to hooked as in Sheldon; regular as in Bartlett to irregular as in Ovid; indistinct as in Ovid to distinct and prominent as in Bantam. Not all pear leaves have clearly visible serrations although all varieties discussed here have some serrated leaves. But certain varieties such as Bosc, Cope's Seedless and Willard have numerous leaves with entire margins. These are usually the older leaves located near the base of shoots or on two-year wood. On the other hand, the leaf margins of Covert are consistently more entire than those of any other variety.

Normal *fall defoliation* is not a particularly valuable character, but the behaviour of Bantam indicates its limited usefulness. With this variety natural shedding of the leaves takes place relatively early.

Leaf pose is a term used to describe the general position taken by the leaves. It is determined largely by the angle of the petiole with the shoot, and the amount of reflexion of the leaf. The amount and type of folding of the blade is also concerned. The leaf pose is not described as such although several individual characters which together determine it are described in previous sections. Undoubtedly the leaf pose of a nursery tree is one of the most significant features used in variety identification in the field because it gives to an observer a composite picture of several important plant characters as shown in the illustrations in the next section.

Prominent Characteristics of Pear Varieties with Illustrations*

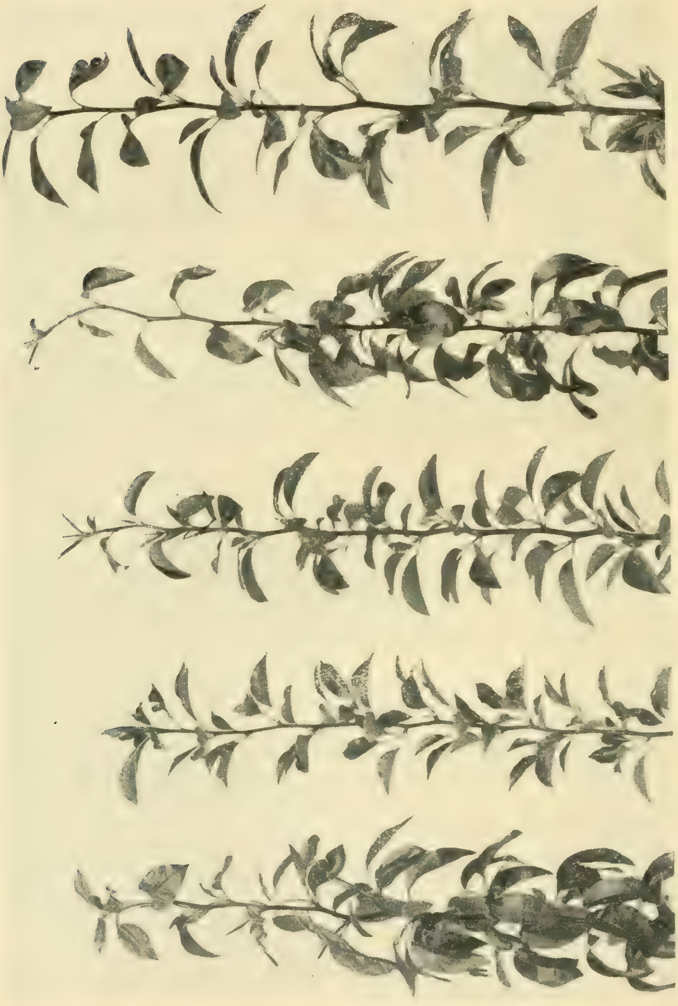
The following pages show illustrations of the upper portions — approximately 2 feet — of one-year shoot growths of 41 pear varieties as they grew in the nursery. Most of the shoots are from one-year trees and are as typical of the variety as could be obtained.

In connection with the illustrations, some of the prominent characteristics of each variety are listed. These are the characteristics which have been found particularly valuable in variety identification in the field, although some of them are more outstanding than others in certain varieties. Also, in many cases, the more complete descriptions in the back part of this bulletin will be found useful and perhaps necessary for positive identification of some varieties. A few unimportant varieties — Bierschmidt, Elizabeth, Endicott, Hardy, Howell, and Lincoln Coreless — are not illustrated but complete descriptions of them are given.

---

*The technical descriptive terms used here are defined and/or illustrated in the section "How Pear Varieties Differ," pages 4-17.

Figure 13


ANJOU
BANTAM
BARTLETT
BOSC
CAYUGA

PROMINENT CHARACTERISTICS

Anjou Two-year bark green overlaid by gray scarfskin; one-year bark green to light brownish green; shoot pubescence heavy; lenticels numerous, raised, often elongated; "leafy" appearance; leaf medium U-folded, reflexed at base of blade, drooping, with crooked midrib; surface often very uneven, yellowish green. (Crooked midribs not prominent in illustration.)

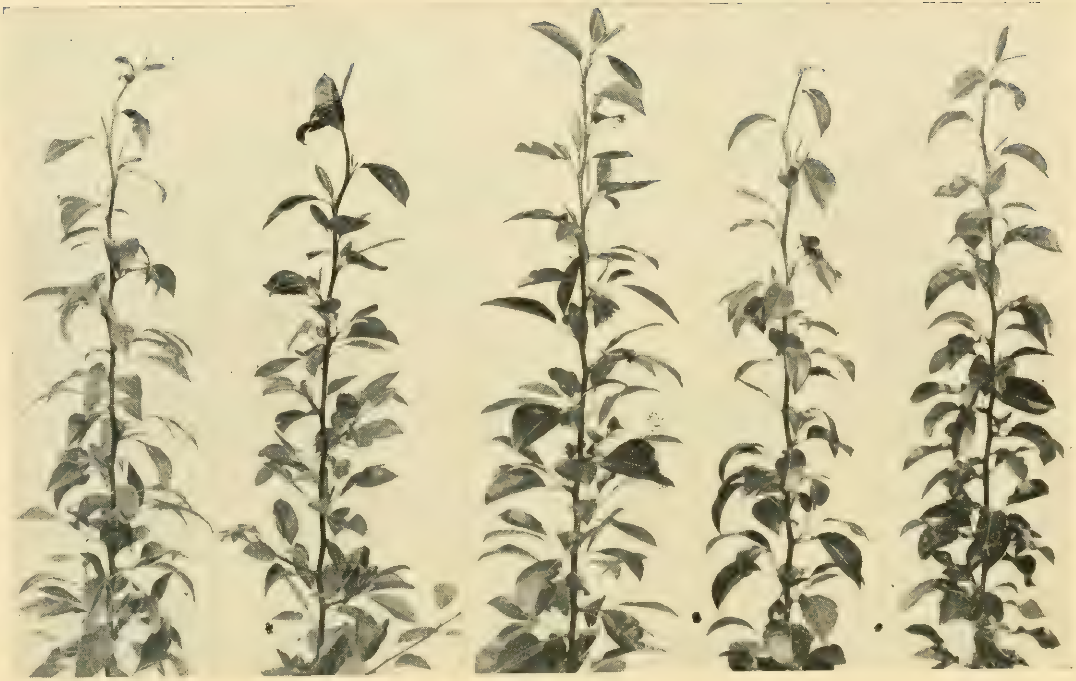
Bantam Habit spreading to drooping; shoots slender, zigzag; shoots dull reddish; petiole long, slender; leaf small, medium to narrow U-folded; tip long acuminate; margin coarsely waved; serrations very sharp (setose serrate), distinct.

Bartlett One-year bark greenish brown; lenticels inconspicuous; leaf medium to narrow U-folded; surface smooth, semi-glossy, dark yellowish green; serrations fine, serrate, regular; leaf position upright spreading.

Bosc Often crooked; two-year bark rather dark grayish brown; one-year bark medium brown; shoot pubescence light; lenticels numerous, large, distinctly raised, conspicuous; leaf rather large, roundish oval to ovate; older leaves reflexed with margins coarsely waved, usually entire.

Cayuga Habit upright; shoots zigzag; one-year bark prevailingly greenish brown; lenticels often elongated; petiole rather wide-angled; leaf long oval to elliptic, not much folded.

Figure 14



CAYWOOD CLAIRGEAU CLAPP FAVORITE CLYDE COMICE

PROMINENT CHARACTERISTICS

Caywood – Shoots zigzag; one-year bark purplish red to reddish brown; shoots reddish to red; lenticels small; leaf rather small, elliptic, not much folded; leaf tip often twisted and reflexed; margin coarsely waved; serrations very prominent.

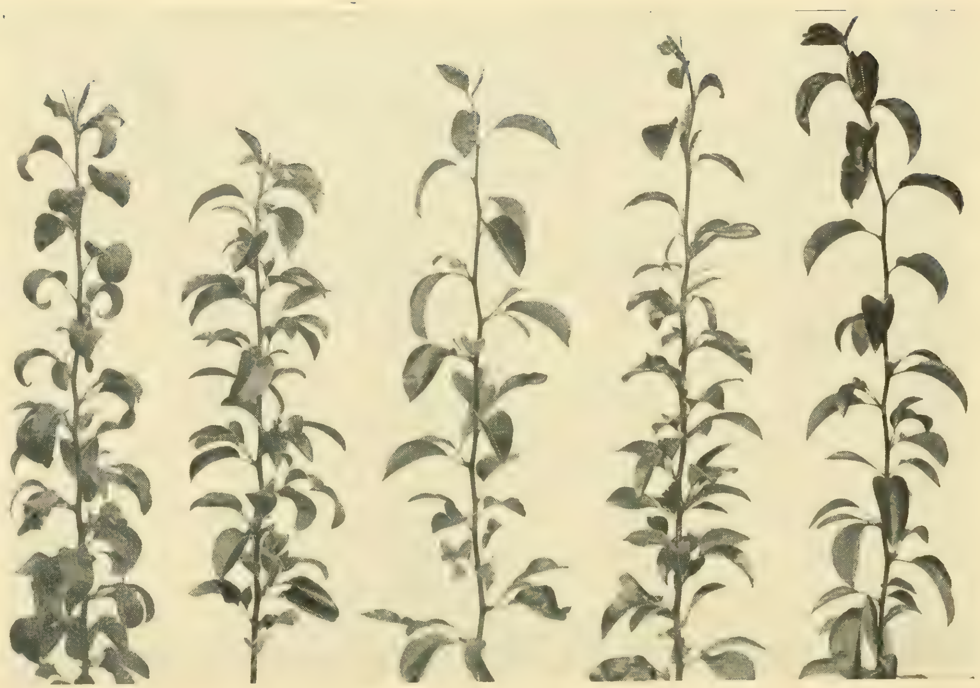
Clairgeau Shoots zigzag; one-year bark reddish brown; shoots reddish; petiole rather long; "leafy" appearance; leaf mostly flat; leaf tip short acuminate; surface dull, medium "muddy" green; serrations very shallow.

Clapp Favorite Rather tall; shoots stout, straight; one-year bark red; lenticels rather few, often elongated even on lower parts of shoots; leaf moderately large, upright to spreading; surface semi-glossy, dark yellowish green.

Clyde Habit upright; shoots moderately slender; one-year bark mostly dull reddish brown; leaf broad oval, broad V-folded, often reflexed; surface smooth, rather glossy; serrations coarse, slightly hooked.

Comice Shoots zigzag; one-year bark green to dull brown; shoots green to pink; lenticels numerous, round, not conspicuous; "leafy" appearance; leaf medium to narrow V-folded, reflexed, sometimes twisted; serrations coarse, deep, hooked. (Narrow V-folding is not shown clearly in the illustration.)

Figure 15



CONFERENCE COPE'S SEEDLESS COVERT DANA HOVEY DOUGLAS

PROMINENT CHARACTERISTICS

Conference Habit upright; shoots stout; internodes short; bark color prevailingly greenish brown; lenticels rather distinct; leaf moderately dark green, broad V-folded with younger leaves often reverse saucer-folded, much reflexed; serrations usually very shallow.

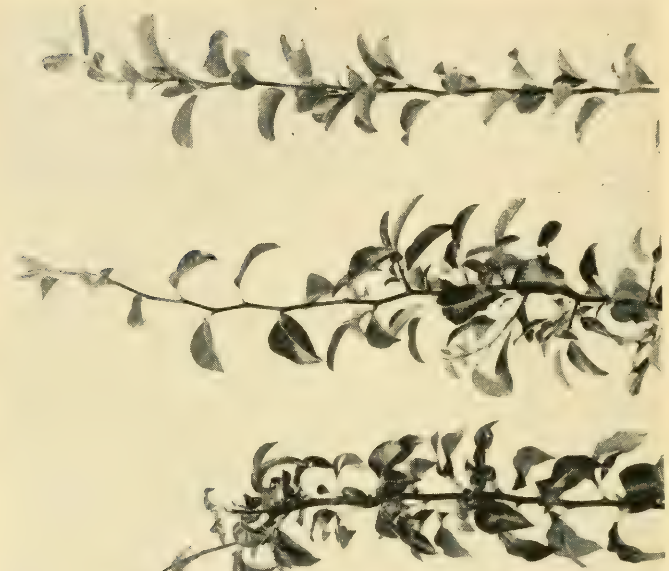
Cope's Seedless — Rather short and often branchy; one-year bark greenish to yellowish brown; shoots often yellowish green; lenticels russet with reddish margins; leaf moderately small, long oval; leaf tip long; serrations coarse, very shallow; younger leaves often entire.

Covert Habit spreading; one-year bark rather dark greenish brown; shoots pink tinged; pubescence light; leaf medium to narrow U-folded, reflexed, drooping; leaf surface dark green; serrations very shallow with most leaves having consistently more nearly entire margins than those of any other variety.

Dana Hovey Habit upright; shoots stout; one year bark green to greenish brown; shoots green; margins of lenticels indistinct; growing tips green; leaf broad elliptic, medium to narrow V folded, reflexed, dark clear green, very glossy. (The leaf folding and reflexion are often more pronounced than in the illustration here.)

Douglas Habit spreading to drooping; shoots often crooked, internodes rather long; young growing shoots reddish; pubescence orange-colored in the vicinity of terminal buds; growing tips red; foliage rather sparse; leaf large (especially tip leaves); petiole and midrib uniformly reflexed; foliage reddens in late summer.

Figure 16


DUCHESS
DUMONT
EARLY SECKEL
EWART
"FALSE BOSC"

PROMINENT CHARACTERISTICS

Duchess — Rather tall; shoots zigzag; two-year bark golden brown; young shoots reddish; growing tips reddish; petiole medium to wide-angled; leaf moderately large, medium U-folded, moderately reflexed at base of blade. (The terminal bud has formed on the shoot in the illustration.)

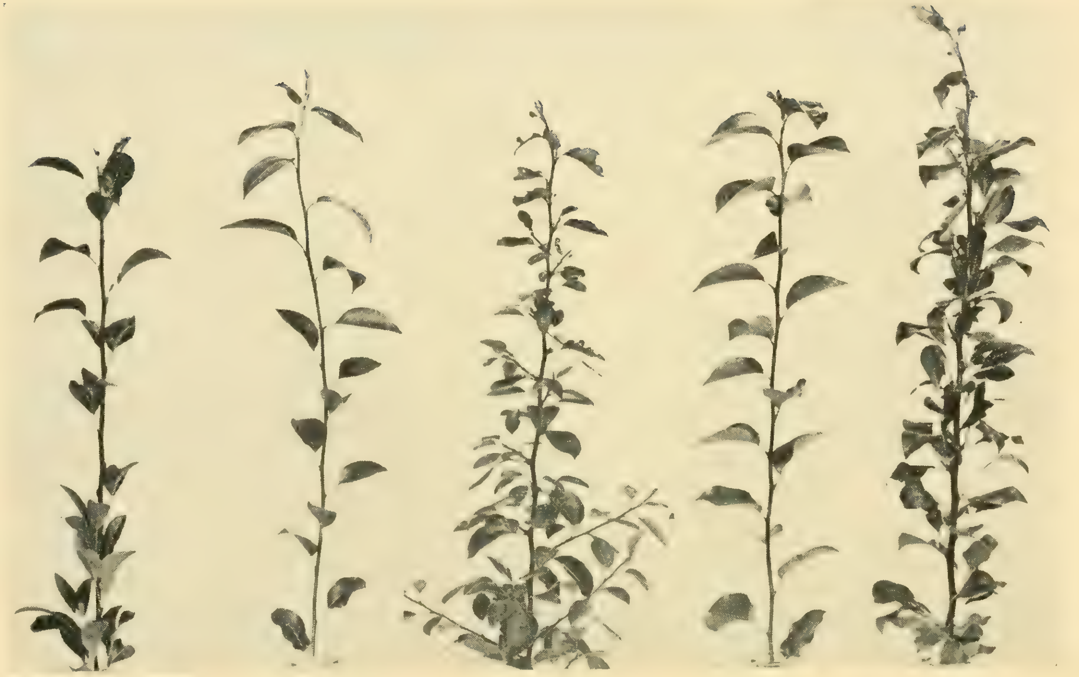
Dumont One-year bark yellowish brown; lenticels few, small, indistinct in outline; leaf roundish oval, very broad V-folded to slightly reverse saucer-folded, much reflexed; surface glossy; midrib distinctly raised; serrations very shallow to almost absent, except on older leaves. (Leaf reflexion is often more pronounced than that shown in the illustration.)

Early Seckel Short; shoots rather stout, typically fasciated and sometimes crooked; one-year bark reddish to reddish brown; lenticels small; growing tips green; leaf flat to reverse saucer-folded (not clearly shown in the illustration), reflexed; rather dark yellowish green.

Ewart Habit spreading; shoots zigzag, often very crooked; one-year bark yellowish brown; pubescence moderately heavy; leaf long oval to elliptic, medium to narrow U-folded; surface moderately glossy; serrations sharply serrate, prominent.

"False Bosc" — Shoots zigzag; one-year bark light greenish brown; young shoots green; lenticels large; pubescence rather heavy extending well down on the shoots; petiole narrow-angled; rather "leafy"; leaf roundish oval, usually broad V-folded; surface pubescent, finely bullate, light yellowish green and mottled.

Figure 17


FLEMISH BEAUTY
GARBER
GORHAM
KIEFFER
KOONCE

PROMINENT CHARACTERISTICS

Flemish Beauty — Shoots slender; one-year bark reddish brown; lenticels small, moderately few; foliage rather sparse; petiole wide-angled; leaf rather small, oval to elliptic, medium green; surface smooth. (Tip elongation has ceased on the shoot in the illustration.)

Garber Tall; internodes mostly long; one-year bark brownish green; young shoots green; pubescence rusty brown near tips; lenticels very numerous, round, white, very conspicuous; leaf large, not much folded; tip acuminate, reflexed; surface moderately rugose along midrib; serrations rather shallow, sharply serrate. (The illustration fails to give proper emphasis to leaf size, and tree vigor.)

Gorham Branchy; one-year bark greenish brown tinged with red; lenticels rather few, small; petiole wide-angled short; "leafy" appearance; leaf small, roundish oval, mostly saucer-folded; leaf tip mucronate; serrations fine, serrate, regular.

Kieffer Habit upright, tall; shoots stout, often greenish brown; pubescence short, rusty brown; growing tips dull reddish; leaf large, oval, stiff, usually upright, rather broadly folded; color rather dark green.

Koonce Tall; one-year bark dull reddish brown; shoots often greenish; pubescence rather heavy, extending well down on the shoots; leaf flat to slightly reverse saucer-folded; color rather light green; surface pubescent (especially on young leaves), slightly rugose; margin coarsely waved; serrations prominent.

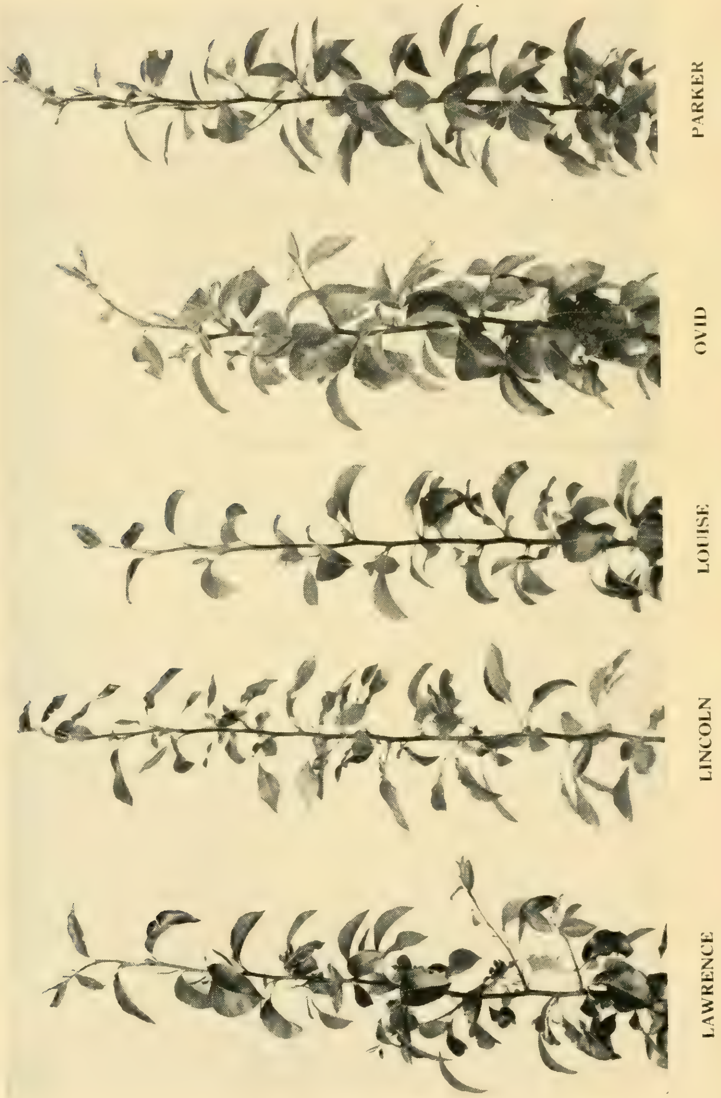

LAWRENCE
LINCOLN
LOUISE
OVID
PARKER

Figure 18

PROMINENT CHARACTERISTICS

Lawrence Shoots moderately slender, straight; internodes short; one-year bark slightly greenish to light brown; lenticels few, small, rather conspicuous; leaf oval, medium to narrow U folded; serrations distinct.

Lincoln Habit spreading; shoots moderately slender; one-year bark green to light brownish; lenticels often elongated; growing tips green; leaf long oval to elliptic; surface lightly pubescent, principal lateral veins numerous, rather light green; margin waved; serrations slightly hooked, prominent.

Louise Shoots rather slender; one-year bark green to purplish brown; shoots dull purplish; leaf moderately small, often narrow U-folded, much reflexed particularly at base of blade; leaf tip reflexed.

Ovid One-year bark green to greenish brown; shoots mostly greenish; lenticels russet with reddish margins; growing tips reddish; petiole wide-angled; leaf roundish oval, broad U-folded, often reflexed; tip mostly mucronate; surface essentially smooth with occasional large depressions; serrations very shallow.

Parker Shoots medium stout; internodes short; one-year bark mostly reddish brown; leaf moderately small, oval to elliptic; medium clear green; serrations fine, shallow, often nearly absent on young leaves; quite similar to Flemish Beauty.

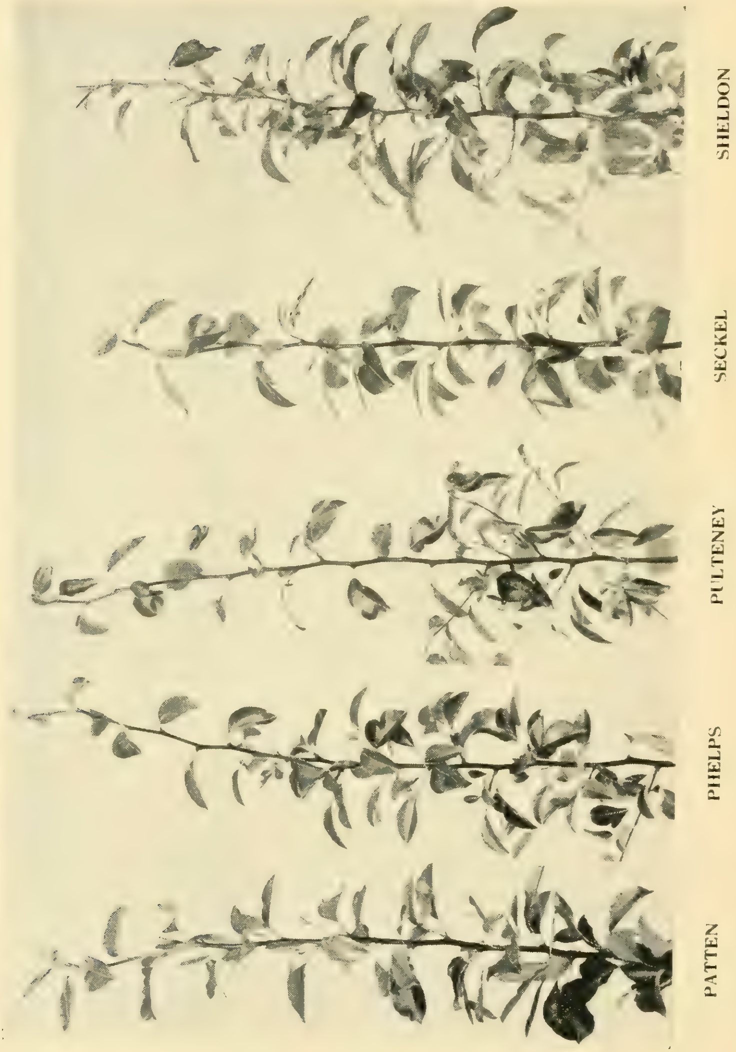

PATTEN
PHELPS
PULTENEY
SECKEL
SHELDON

Figure 19

PROMINENT CHARACTERISTICS

Patten Habit upright, tall; shoots rather stout; bark somewhat purplish throughout; lenticels often elongated; leaves on upper parts of shoots rather strongly U-folded; leaf surface finely bullate, moderately glossy, dark yellowish green; margin coarsely waved.

Phelps Rather tall; shoots moderately slender, zigzag; one-year bark greenish brown; lenticels rather large' russet, rather conspicuous; leaf ovate, medium U-folded; surface dark yellowish green; serrations very shallow and indistinct.

Pulteney One-year bark yellowish brown; shoots yellowish green to reddish tinged; growing tips reddish; leaf usually broad U-folded to slightly saucer-folded, often twisted; leaf tip mucronate; surface semi-glossy to glossy.

Seckel Rather short; one-year bark greenish brown tinged with red; lenticels small; leaf roundish oval, very broad V-folded to reverse saucer-folded; surface fine-textured, slightly rugose, glossy, moderately dark clear green.

Sheldon - One-year bark yellowish brown, shoots mostly yellowish green; leaf moderately small, elliptic, broad to medium V-folded, reflexed midrib; base moderately narrow and rounded; color light yellowish green; margin coarsely waved; serrations prominent, slightly hooked.

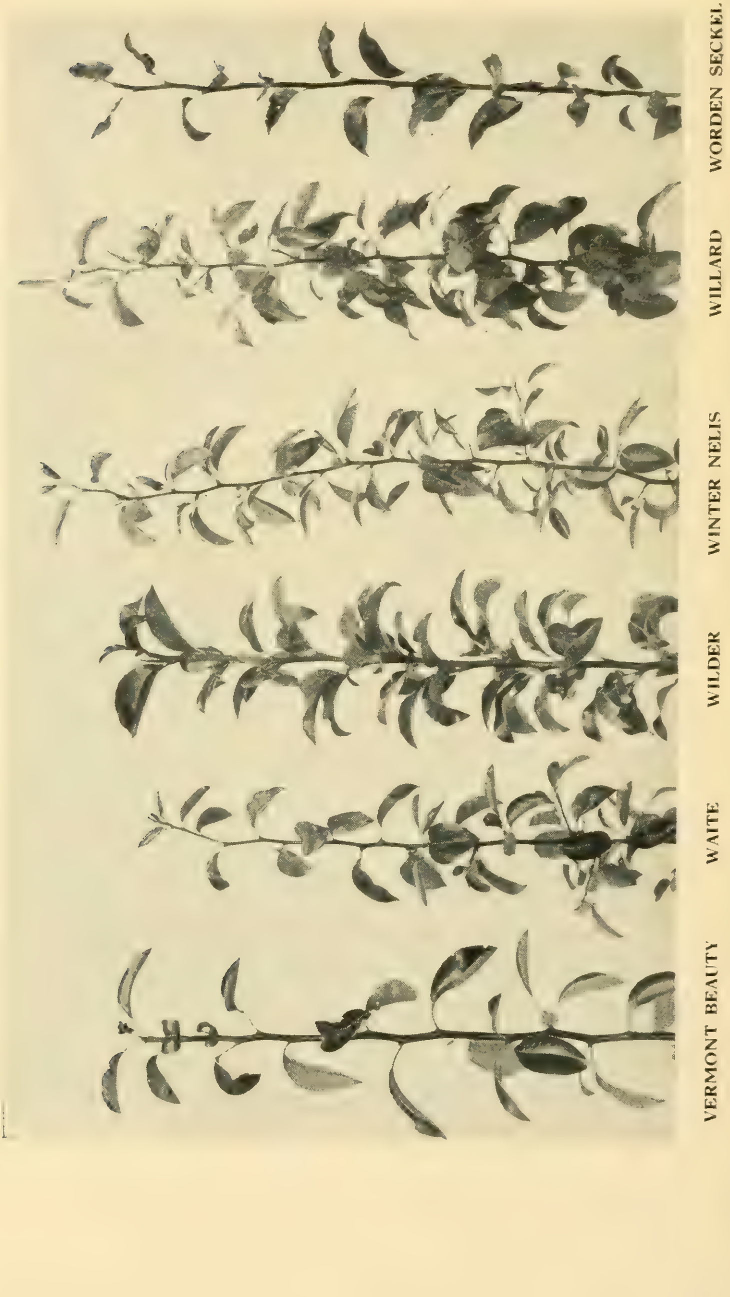

VERMONT BEAUTY
WAITE
WILDER
WINTER NELIS
WILLARD
WORDEN SECKEL

Figure 20

PROMINENT CHARACTERISTICS

Vermont Beauty -- Shoots rather slender, zigzag; one-year bark reddish brown; shoots reddish; lenticels rather small, distinct; growing tips green; petiole wide-angled, long; foliage rather sparse; leaf essentially elliptic, broadly folded, reflexed, spreading to drooping; surface rather fine-textured. (The terminal bud has formed on the shoot illustrated.)

Waite — Often branchy; internodes short; one-year bark greenish brown; lenticels small, moderately raised; "leafy" appearance; leaf moderately small, mostly oval, medium U-folded, with tendency to crooked midrib; serrations variable in size and depth, serrate.

Wilder - Habit upright, tall; shoots stout; one-year bark light reddish; shoots pink; lenticels often elongated; petiole narrow-angled, short; "leafy" appearance; leaf oval to ovate, broad V-folded, reflexed at base and apex; color rather light "silvery" green. (The illustration may give the impression of a dark green.)

Winter Nelis Habit spreading; shoots rather slender, often crooked; one-year bark greenish to yellowish brown; shoots light reddish; lenticels on two-year bark often elongated laterally; growing tips red; petiole wide-angled; leaf rather small; color medium yellowish green with some mottling.

Willard One-year bark green to greenish brown; young shoots green; lenticels rather conspicuous; growing tips mostly green; "leafy" appearance; leaf rather large, ovate, flat to saucer-folded; surface smooth except for raised principal veins, dark clear green; serrations fine; younger leaves nearly entire.

Worden Seckel - - Shoots zigzag; one-year bark dark greenish to yellowish brown; foliage rather sparse; leaf rather small, oval to ovate, flat to very broad V-folded; surface smooth, rather dull, moderately light yellowish green and usually mottled.

Variety Comparisons*

From the standpoint of separating possible mixtures in a nursery row or of determining whether a row is correctly labeled, it is very desirable to know the important differences between pear varieties which are similar or likely to be mixed. Instead of critically comparing the newer varieties with one another, it seemed better in most cases to compare each with an important familiar variety with which it has some resemblance. In the following selected varietal comparisons, several of them between varieties which have been found mixed in commercial nurseries, some of the more signficant differences are given.

1.	**Cayuga**	**Bartlett**
Habit	Upright	Upright-spreading
Height	Moderately tall	Medium
Bark (*2-year*)	Medium brown	Medium yellowish brown
Leaf		
Shape	Long oval to elliptic	Oval
Folding	Flat to broad U	Usually medium but occasionally narrow U
Color	Moderately light to medium green	Dark yellowish green
Serrations	Medium to coarse, shallow, dull serrate	Fine, moderately shallow, serrate

2.	**Caywood**	**Sheldon**
Bark (*2-year*)	Purplish brown	Light to medium brown
(*1-year*)	Purplish red to reddish brown	Yellowish brown
Leaf		
Folding	Flat to broad U or V	Broad to medium V
Surface	Rather dull	Moderately semi-glossy
Color	Medium green	Light yellowish green
Serrations	Moderately coarse	Mostly medium

3.	**Clapp Favorite**	**Flemish Beauty**
Height	Medium to moderately tall	Medium
Shoots	Stout	Slender
Bark (*2-year*)	Reddish brown	Rather dark brown, somewhat grayish
(*1-year*)	Red	Reddish brown
Lenticels	Few, often elongated	Moderately few

---

*The technical descriptive terms used here are defined and/or illustrated in the section "How Pear Varieties Differ," pages 4-17.

Leaf		
Size	Moderately large	Small
Shape	Oval	Oval to elliptic
Color	Dark green	Medium green

4.	**Clyde**	**Seckle**
Shoots	Moderately slender, somewhat zigzag	Medium stout, slightly zigzag
Petiole	Moderately long, reddish tinged	Short, green
Leaf		
Shape	Broad oval to slightly ovate	Roundish oval
Surface	Smooth	Slightly rugose
Color	Moderately dark yellowish green	Moderately dark, clear green
Serrations	Shallow, margin often practically entire	Moderately shallow

5.	**Comice**	**Sheldon**
Shoots	Zigzag	Moderately zigzag
Bark (2-*year*)	Greenish brown	Light to medium brown
(1-*year*)	Prevailingly green to dull brown	Yellowish brown
Lenticels	Numerous	Medium
Leaf		
Size	Medium	Moderately small
Folding	Typically medium to narrow V	Broad to medium V
Color	Rather dark green	Light yellowish green

6.	**Cope's Seedless**	**Bartlett**
Habit	Spreading	Upright-spreading
Petiole	Wide-angled	Medium-angled
Leaf		
Shape	Long oval	Oval
Folding	Rather broad U	Usually medium to occasionally narrow U
Surface	Rather dull	Semi-glossy
Color	Medium green	Dark yellowish green
Tip	Long, acute	Small, acute
Serrations	Coarse, very shallow, younger leaves often entire	Fine, moderately shallow

7.	**Covert**	**Willard**
Bark (2-year)	Grayish green	Greenish brown
(1-year)	Rather dark, very greenish brown	Green to greenish brown
Growing tips	Slightly to moderately reddish tinged	Mostly green
Leaf		
Shape	Oval	Ovate
Folding	Medium to narrow U	Flat to broad U or saucer
Reflexion	Usually much reflexed, drooping	Often reflexed
Color	Very dark green, rather light green on underside	Dark, clear green, grayish on underside
Serrations	Majority of leaf margins entire	Only margins of younger leaves nearly entire

8.	**Douglas**	**Duchess**
Habit	Spreading to drooping	Rather upright
Shoots	Often crooked	Not crooked
Bark (2-year)	Moderately light to medium brown	Golden brown
(1-year)	Brown	Reddish brown
Pubescence	Medium in amount, orange-colored near terminal buds	Rather sparse
Leaf		
Size	Rather large	Moderately large
Reflexion	Uniform through petiole and midrib	Mostly at base of blade
Color	Rather dark yellowish green, turning red in early fall	Medium green
Serrations	Very coarse, very shallow	Moderately coarse, moderately shallow

9.	**Dumont**	**Conference**
Bark (2-year)	Greenish brown to moderately light brown	Rather dark greenish brown
(1-year)	Yellowish brown	Greenish brown
Lenticels	Few, small, not distinct in outline	Medium in number and size, rather distinct
Growing tips	Reddish tinged	Slightly pinkish tinged
Leaf		
Shape	Roundish oval	Moderately long oval
Surface	Glossy	Semi-glossy
Color	Medium to moderately dark yellowish green	Moderately dark green

10.	**Early Seckel**	**Seckel**
Shoots	Typically fasciated and sometimes crooked	Not fasciated or crooked
Bark (1-year)	Reddish brown to reddish	Greenish brown tinged with red
Lenticels	Rather numerous	Medium in number
Leaf		
Shape	Oval	Roundish oval
Folding	Flat to reverse saucer, (prominently reverse saucer on older leaves)	Very broad V to reverse saucer
Surface	Semi-glossy	Fine textured, glossy
Color	Rather dark yellowish green	Moderately dark, clear green

11.	**Ewart**	**Bartlett**
Habit	Spreading	Upright-spreading
Shoots	Often very crooked	Usually straight
Bark (2-year)	Light grayish brown	Medium yellowish brown
(1-year)	Yellowish brown	Greenish brown
Leaf		
Shape	Long oval to elliptic	Oval
Folding	Often narrow U	Occasionally narrow U
Color	Moderately light to medium yellowish green	Dark yellowish green
Serrations	Medium in size, sharply serrate, prominent	Fine, serrate

12.	**"False Bosc"**	**Bosc**
Shoots	Usually straight	Often crooked.
Bark (2-year)	Rather dark greenish brown	Rather dark grayish brown
(1-year)	Light greenish brown	Medium brown
Young shoots	Green	Reddish tinged
Pubescence	Rather heavy	Light
Lenticels	Flush, russet	Raised, very conspicuous
Petiole	Narrow-angled	Moderately wide-angled
Leaf		
Folding	Rather broad V	Flat to broad U
Surface	Bullate, pubescent	Smooth
Color	Light yellowish green, mottled	Moderately dark yellowish green
Serrations	Rather regular	Often lacking on older leaves

13.	**Garber**	**Kieffer**
Habit	Upright-spreading	Upright
Bark (*2-year*)	Brownish green and grayish	Greenish to somewhat reddish brown
Young shoot color	Green	Greenish brown
Lenticels	Very numerous, white, very conspicuous	Moderately few to medium in number
Petiole	Narrow-angled but reflexed	Moderately wide-angled
Leaf		
Shape	Long oval	Oval
Folding	Flat to very broad V or slightly reverse saucer	Broad to medium U or V
Tip	Acuminate, prominent	Acute
Surface	Moderately rugose, especially along midrib	Smooth with net veins uniformly depressed
Color	Medium clear green	Rather dark green
Serrations	Sharply serrate, prominent	Dull serrate

14.	**Gorham**	**Pulteney**
Bark (*1-year*)	Greenish brown tinged with red	Yellowish brown
Young shoots	Reddish tinged	Yellowish green to reddish tinged
Growing tips	Reddish tinged	Reddish
Leaf		
Shape	Roundish oval	Moderately long oval to slightly obovate
Folding	Mostly saucer	Broad to medium U to slightly saucer
Twisting	Seldom twisted	Often twisted
Serrations	Fine, medium in depth, regular, distinct	Medium, very shallow, irregular

15.	**Lawrence**	**Sheldon**
Shoots	Straight	Moderately zigzag
Bark (*1-year*)	Slightly greenish to light brown	Yellowish brown
Shoot pubescence	Light	Moderately heavy
Lenticels	Rather conspicuous	Not conspicuous
Leaf		
Size	Medium	Moderately small
Shape	Oval	Elliptic
Folding	Medium to narrow U	Broad to medium V

16.	**Lincoln**	**Sheldon**
Shoots	Moderately slender	Medium stout
Bark (1-*year*)	Green to light brownish	Yellowish brown
Lenticels	Medium in size, light russet, often elongated	Rather small, russet
Growing tips	Green	Reddish tinged to slightly reddish
Foliage density	Sparse	Leafy
Leaf	Less reflexed	
Color	Medium to rather light green	Light yellowish green

17.	**Parker**	**Flemish Beauty**
Height	Medium to rather tall	Medium
Shoots	Medium stout	Slender
Young shoot color	Reddish tinged	Reddish
Leaf		
Size	Moderately small	Small
Tip	Acute	Acute to acuminate
Serrations	Dull serrate, many young leaves practically entire	Serrate

As seen by the writers these varieties have many similarities.

18.	**Phelps**	**Bartlett**
Height	Tall	Medium
Shoots	Moderately slender	Medium stout
Lenticels	Rather conspicuous	Inconspicuous
Growing tips	Reddish tinged to reddish	Green to reddish tinged
Foliage density	Moderately sparse	Average
Leaf		
Shape	Ovate	Oval
Serrations	Very shallow, irregular, indistinct	Moderately shallow, regular, distinct

19.	**Pulteney**	**Bartlett**
Lenticels	Slightly raised	Flush
Petiole	Moderately long	Rather short
Growing tips	Reddish	Green to reddish tinged
Leaf		
Size	Moderately small	Medium
Shape	Moderately long oval to slightly obovate	Oval
Folding	Broad to medium U to slightly saucer	Usually medium but occasionally narrow U
Midrib	Sometimes twisted	
Tip	Mucronate	Small, acute
Serrations	Very shallow, irregular	Moderately shallow, regular

20.	**Willard**	**Bosc**
Habit	Essentially straight	Often crooked
Bark (2-year)	Greenish brown	Rather dark grayish brown
(1-*year*)	Green to greenish brown	Medium brown
Growing tips	Mostly green	Reddish tinged
Leaf		
Margin	Mostly even	Coarsely waved, especially on older leaves
Surface	Veins distinctly raised, rugose along midrib	Smooth
Color	Dark, clear green	Moderately dark yellowish green
Serrations	Fine, usually very shallow, margins of younger leaves nearly entire	Rather coarse, rather shallow, hooked, margins of old leaves usually entire

21.	**Worden Seckel**	**Seckel**
Height	Medium	Rather short
Shoots	Moderately slender, zigzag	Medium stout, slightly zigzag
Foliage density	Sparse	Average
Leaf		
Size	Rather small	Medium
Shape	Oval to ovate	Roundish oval
Folding	Flat to very broad V	Very broad V to reverse saucer
Surface	Rather dull	Glossy
Color	Moderately light yellowish green, usually mottled	Moderately dark, clear green

Variety Key

A variety key is strictly an arbitrary classification of varieties based on a few selected characteristics and arranged in such a way that a variety may be identified rather quickly by following through the key. However, such a key is far from infallible since it is based on characteristics that exhibit natural variation, as for example, color and size. Furthermore, with pears it has seemed to be more difficult to construct a workable key than with some other fruits. The following key is based on plant characters of healthy and vigorous one- and two-year-old nursery trees as they appeared in July and early August. Forty-one varieties are included.

KEY TO SOME PEAR VARIETIES

- A Leaf usually ovate or oval to ovate
  - B One-year bark light reddish........................Wilder
  - BB One-year bark greenish to brownish
    - C Lenticels small, flush........................Worden Seckel
    - CC Lenticels medium to large, at least somewhat raised
      - D Lateral veins distinctly raised, growing tips green......Willard
      - DD Lateral veins not distinctly raised, growing tips reddish tinged
        - E Leaf flat to broad U-folded..................Bosc
        - EE Leaf medium U-folded......................Phelps
- AA Leaf usually oval or roundish oval
  - B One-year bark more or less purplish
    - C Leaf small, usually narrow U-folded, serrations rather coarse...Louise
    - CC Leaf large, usually broad U-folded, serrations moderately fine..Patten
  - BB One-year bark essentially red or reddish brown
    - C Serrations setose serrate, prominent........................Bantam
    - CC Serrations serrate or dull serrate
      - D Leaf surface dull................................Clairgeau
      - DD Leaf surface at least semi-glossy
        - E Growing tips green, shoots often fasciated.....Early Seckel
        - EE Growing tips reddish tinged, shoots not fasciated
          - F Shoots stout, leaf serrations fine.........Clapp Favorite
          - FF Shoots moderately slender, serrations coarse............Clyde
  - BBB One-year bark greenish brown tinged with red
    - C Shoot pubescence rusty brown........................Kieffer
    - CC Shoot pubescence white or gray
      - D Leaf semi-glossy, saucer-folded....................Gorham
      - DD Leaf distinctly glossy, broad V- to reverse-saucer-folded..........Seckel
  - BBBB One-year bark usually greenish brown or yellowish brown
    - C Upper leaf surface pubescent and finely bullate..............."False Bosc"
    - CC Upper leaf surface not pubescent or finely bullate
      - D Leaf broad V- to reverse saucer-folded, glossy.........Dumont
      - DD Leaf broad U-folded, not more than semi-glossy.......Ovid
      - DDD Leaf medium to narrow U-folded, not more than semi-glossy
        - E Serrations very shallow, dull serrate, very often absent, lateral veins raised... ....Covert
        - EE Serrations serrate and almost always evident, lateral veins not raised
          - F Lenticels flush
            - G Lenticels whitish, rather conspicuous ....Lawrence
            - GG Lenticels russet, inconspicuous.....Bartlett
          - FF Lenticels moderately raised.............Waite

- AAA Leaf usually long oval or elliptic
  - B One-year bark usually reddish brown
    - C Leaf blade moderately large (even to tips of shoots) .... Duchess
    - CC Leaf blade moderately small
      - D Leaf margin coarsely waved
        - E Surface smooth, not pubescent .... Caywood
        - EE Surface slightly rugose with depressed veins, pubescent .... Koonce
      - DD Leaf margin essentially even
        - E Growing tips green .... Vermont Beauty
        - EE Growing tips reddish tinged
          - F Leaf tip acute to acuminate, surface moderately semi-glossy, serrations serrate ... Flemish Beauty
          - FF Leaf tip acute, surface dull, serrations dull serrate with many young leaves practically entire .... Parker
  - BB One-year bark greenish brown, yellowish brown, or brown
    - C Crooked growth
      - D Shoots slender, growing tips red .... Winter Nelis
      - DD Shoots stout, growing tips reddish tinged .... Ewart
    - CC Reasonably straight growth
      - D Leaf very glossy .... Dana Hovey
      - DD Leaf semi-glossy to dull
        - E Leaf essentially flat .... Garber
        - EE Leaf broad to medium V-folded
          - F Serrations rather deep, margin coarsely waved .... Sheldon
          - FF Serrations very shallow, margin mostly even .... Conference
        - EEE Leaf medium to narrow V-folded .... Comice
        - EEEE Leaf usually U-folded
          - F Pubescence near terminal orange .... Douglas
          - FF Pubescence near terminal white or gray
            - G Leaf rather large with crooked midrib, drooping .... Anjou
            - GG Leaf moderately small to medium, not drooping
              - H Serrations moderately deep, prominent .... Lincoln
              - HH Serrations shallow to very shallow
                - I Grownig tips green to reddish tinged
                  - J Leaf tip long, shoots mostly straight .... Cope's Seedless
                  - JJ Leaf tip medium in length, shoots zigzag .... Cayuga
                - II Growing tips reddish ..... Pulteney

VARIETY DESCRIPTIONS*

1. Anjou (Buerré d'Anjou). Habit upright-spreading, moderately tall; shoots medium stout, somewhat zigzag: internodes moderately long. Two-year bark green overlaid by heavy broken gray scarfskin; one-year bark green to light brownish green; young shoots green with pinkish tinge; pubescence heavy; lenticels rather numerous, medium in size, raised, somewhat whitish, very often elongated. Growing tips pinkish tinged. Petiole moderately wide-angled, moderately long, medium thick, reddish tinged. Rather "leafy"; leaf blade moderately large, long oval to elliptic, broad to narrow U-folded, with crooked midrib, reflexed at base of blade, drooping; base medium; apex moderately narrow, sometimes reflexed; tip long acute; surface slightly rugose and moderately to very uneven, semi-glossy, light to medium yellowish green; margin coarsely waved: serrations medium to coarse, shallow, very dull serrate, rather regular.

2. Bantam. Habit spreading to drooping, branchy, rather tall; shoots slender, zigzag, slightly crooked; internodes rather long. Two-year bark dark grayish brown; one-year bark dull reddish brown; young shoots dull reddish; pubescence very light; lenticels medium in number, small, flush, slightly whitish. Growing tips reddish tinged. Petiole medium-angled, long, slender, green. Leaf blade small, oval, typically medium to narrow U-folded, occasionally rolled, slightly reflexed, thin; base moderately full; apex moderately narrow; tip long acuminate; surface smooth, semi-glossy, moderately dark green; margin coarsely waved; serrations moderately fine, rather deep, setose serrate, moderately regular, distinct and prominent.

3. Bartlett. Habit upright-spreading, medium in height; shoots medium stout, moderately zigzag; internodes moderately short. Two-year bark medium yellowish brown; one-year bark greenish brown; young shoots green to slightly reddish tinged; pubescence medium; lenticels medium in number and size, flush, russet, inconspicuous. Growing tips green to reddish tinged. Petiole medium-angled, rather short, medium in thickness, green to slightly reddish tinged. Leaf blade medium in size, oval, usually medium but occasionally narrow U-folded; base and apex moderately full; tip small acute; surface smooth, semi-glossy, dark yellowish green; margin even; serrations fine, moderately shallow, serrate, regular.

4. Bierschmidt. Habit upright, medium in height; shoots medium stout, mostly straight; internodes short. Two-year bark greenish or yellowish brown; one-year bark green to greenish brown; young shoots pink; pubescence rather heavy; lenticels moderately few, medium in size, slightly raised, mostly russet with red margin, not conspicuous. Growing tips reddish tinged. Petiole medium-angled, medium in length and thickness, reddish tinged. Leaf blade medium in size, oval to slightly ovate, flat to moderately broad U-folded with crooked midrib, reflexed; base moderately full; apex moderately full, occasionally reflexed; surface smooth to slightly rugose, moderately semi-glossy, rather dark green; margin slightly waved: serrations medium in size, shallow, dull serrate, somewhat irregular.

5. Bosc (Buerré Bosc). Habit upright-spreading, moderately tall, often crooked; shoots medium stout, somewhat zigzag; internodes medium. Two-year bark rather dark grayish brown; one-year bark medium brown; young shoots reddish tinged; pubescence light; lenticels numerous, large, distinctly raised, slightly whitish, very conspicuous. Growing tips reddish tinged. Petiole moderately wide-angled, medium in length and thickness, reddish tinged. Leaf blade rather large, roundish oval to ovate, flat to broad U-folded, often reflexed; base full; apex moderately full, twisted and reflexed; surface smooth, moderately semi-glossy, moderately dark yellowish green; margin coarsely waved, especially on older leaves; serrations rather coarse, rather shallow, hooked, serrate, irregular, older leaves usually entire.

6. Cayuga. Habit upright, moderately tall; shoots medium stout, zigzag; internodes moderately long. Two-year bark medium brown; one-year bark greenish brown; young shoots pinkish tinged to moderately reddish tinged; pubescence light; lenticels medium in number and size, flush, russet, often elongated. Growing tips green to reddish tinged. Petiole moderately wide-angled, moderately long, moderately slender, reddish tinged. Leaf blade medium in size, long oval to elliptic, flat to broad U-folded; base moderately narrow; apex medium to narrow; surface smooth, semi-glossy, moderately light green to medium green; margin even to somewhat coarsely waved; serrations medium to coarse, shallow, dull serrate, irregular.

7. Caywood. Habit upright-spreading, medium in height; shoots moderately slender, zigzag; internodes medium. Two-year bark purplish brown; one-year bark purplish red to reddish brown;

---

*The technical descriptive terms used here are defined and/or illustrated in the section "How Pear Varieties Differ". pages 4 - 17.

young shoots reddish to red; pubescence medium; lenticels medium in number, small, flush, slightly white. Growing tips green to light reddish tinged. Petiole moderately wide-angled, short to medium in length, rather slender, reddish tinged. Leaf blade moderately small, elliptic, flat to broad U- or V-folded; base rather narrow; apex rather narrow, slightly twisted and usually reflexed; tip acute to acuminate; surface smooth, rather dull, medium green; margin coarsely waved; serrations moderately coarse, medium in depth, serrate, usually regular, prominent.

8. Clairgeau (Buerré Clairgeau). Habit upright, medium in height; shoots moderately stout, zigzag; internodes medium. Two-year bark medium brown; one-year bark reddish brown; young shoots reddish; pubescence light to medium; lenticels moderately numerous, medium in size, flush to slightly raised, russet. Growing tips slightly reddish tinged. Petiole wide-angled, medium to moderately long, moderately slender, reddish tinged to reddish. Rather "leafy"; leaf blade medium in size, oval, flat to slightly broad U-folded, sometimes reverse saucer-folded near growing tip; base and apex moderately full; tip short acuminate; surface slightly rugose with occasional large shallow depressions on younger leaves, dull, medium "muddy" green (not a clear color); margin even to slightly coarsely waved; serrations medium in size, very shallow, dull serrate, rather regular.

9. Clapp Favorite. Habit upright to upright-spreading, medium to moderately tall; shoots stout, straight; internodes medium. Two-year bark reddish brown; one-year bark red; young shoots pink; pubescence light to medium; lenticels few, medium in size, flush, often elongated even on lower parts of shoots; moderately whitish. Growing tips reddish tinged. Petiole moderately narrow-angled, medium to moderately long, medium thick, green to reddish tinged. Leaf blade moderately large, oval, broad U-folded or V-folded, upright to spreading; base and apex moderately full; tip acute; surface smooth, semi-glossy, dark yellowish green; margin even to slightly coarsely waved; serrations fine, shallow, dull serrate, regular.

10. Clyde. Habit upright, short to medium; shoots moderately slender, somewhat zigzag; internodes medium. Two-year bark rather dark grayish brown tinged with green; one-year bark dull reddish brown tinged with green; young shoots pink to reddish; pubescence medium; lenticels medium in number, moderately small, flush, mostly russet, sometimes elongated. Growing tips reddish tinged. Petiole medium-angled, moderately long, medium thick, reddish tinged. Leaf blade medium in size, broad oval to slightly ovate, broad V-folded, sometimes much reflexed; base rather full; apex rather full, reflexed; surface smooth, rather glossy, moderately dark yellowish green; margin mostly even; serrations coarse, shallow, dull serrate, slightly hooked, rather irregular, some leaves practically entire.

11. Comice. (Doyenné du Comice). Habit upright-spreading, medium in height; shoots medium stout, zigzag; internodes short. Two-year bark greenish brown; one-year bark prevailingly green to dull brown; young shoots pink; pubescence medium; lenticels numerous, medium in size, round, slightly raised, russet, not conspicuous. Growing tips reddish tinged to reddish. Petiole medium-angled, medium in length, moderately thick, reddish tinged. Rather "leafy"; leaf blade medium in size, oval to elliptic, typically medium to narrow V-folded, considerably reflexed, sometimes twisted; base and apex moderately full; surface slightly bullate, semi-glossy to dull, rather dark green; margin moderately coarsely waved; serrations rather coarse, rather deep, serrate, hooked, regular, moderately prominent.

12. Conference. Habit upright, medium in height; shoots stout, rather zigzag; internodes short. Two-year bark rather dark greenish brown; one-year bark greenish brown; young shoots mostly green; pubescence medium; lenticels medium in number and size, flush, russet, rather distinct. Growing tips slightly pinkish tinged. Petiole medium-angled, rather short, rather slender, mostly green. Leaf blade medium in size, moderately long oval, broad V-folded and often with younger leaves somewhat reverse saucer-folded, much reflexed; base moderately full; apex moderately full, reflexed; tip acute; surface essentially smooth with some rugoseness on leaves near shoot tips, semi-glossy, moderately dark green; margin mostly even; serrations rather fine to coarse and widespread, serrate, very shallow, moderately regular (leaves on the lower middle section of one-year growth may have coarse and prominent serrations).

13. Cope's Seedless. Habit upright-spreading, branchy, rather short to medium in height; shoots medium stout, straight to slightly zigzag; internodes short to medium. Two-year bark medium brown; one-year bark greenish to yellowish brown; young shoots yellowish green to slightly reddish tinged; pubescence light; lenticels medium in number, moderately small, mostly flush, russet with reddish margins, inconspicious. Growing tips green to reddish tinged. Petiole wide-angled, medium in length and thickness, reddish tinged. Leaf blade moderately small, long oval, rather broad U-folded; base moderately full; apex moderately narrow; tip long acute; surface smooth, rather dull, medium green; margin even; serrations coarse, very shallow, serrate, irregular; younger leaves often entire.

14. Covert. Habit mostly spreading, medium to tall; shoots moderately stout, slightly zigzag, slightly crooked; internodes medium. Two-year bark grayish green; one-year bark rather dark, very greenish brown; young shoots pinkish tinged; pubescence light; lenticels medium in number, moderately large, mostly flush, mostly russet, rather prominent. Growing tips slightly to moderately reddish tinged. Petiole moderately wide-angled, medium in length, moderately thick, reddish tinged. Rather "leafy"; leaf blade moderately large, oval, medium to narrow U-folded, much reflexed, drooping; base full; apex moderately full; tip short acuminate but distinct, point often upturned; surface smooth with raised lateral veins, semi-glossy, very dark green; margin even; serrations medium in size, very shallow, dull serrate, irregular, often lacking (a majority of the leaves have entire or practically entire margins).

15. Dana Hovey. Habit upright, moderately tall; shoots stout, slightly zigzag; internodes medium. Two-year bark greenish to somewhat grayish brown; one-year bark green to brownish green; young shoots green; pubescence light; lenticels rather few, moderately large, flush, russet, often not distinct in outline. Growing tips green. Petiole slightly narrow to medium-angled, medium in length, rather thick, green. Leaf blade rather large, broad elliptic, often medium to narrow V-folded with a suggestion of reverse saucer folding, reflexed; midrib inclined to be crooked; base and apex moderately narrow; tip acute to acuminate; surface smooth to slightly rugose, very glossy, dark clear green; margin coarsely waved; serrations medium in size, moderately shallow, serrate, often irregular.

16. Douglas. Habit spreading to drooping, medium to tall; shoots medium stout, moderately zigzag, often crooked; internodes rather long. Two-year bark moderately light to medium brown; one-year bark brown; young shoots reddish; pubescence medium, orange colored near terminal buds; lenticels medium in number, moderately small, round, slightly raised, russet. Growing tips red. Petiole rather wide-angled, medium in length and thickness, reddish. Foliage rather sparse. Leaf blade rather large (even to shoot tips, especially after terminal bud is formed), long oval, medium to narrow U-folded, reflexed uniformly through petiole and midrib; base and apex moderately full; tip acute; surface smooth, semi-glossy, rather dark yellowish green, often rather red in late summer; margin even to slightly coarsely waved; serrations very coarse, very shallow, dull serrate, irregular.

17. Duchess (Duchesse d'Angoulême). Habit rather upright, medium to tall; shoots medium stout, zigzag; internodes medium. Two-year bark golden brown; one-year bark reddish brown; young shoots pink to reddish; pubescence rather light; lenticels medium in number and size, slightly raised, somewhat whitish. Growing tips reddish. Petiole medium to wide angled, medium in length and thickness, reddish tinged. Leaf blade moderately large (even to shoot tips, especially after terminal bud is formed), long oval to slightly long obovate, medium U-folded, moderately reflexed, mostly at base of blade, twisted; base moderately narrow; apex moderately full; surface smooth, semi-glossy, medium green; margin even to slightly coarsely waved; serrations moderately coarse, moderately shallow, dull serrate, irregular.

18. Dumont (Buerré Dumont). Habit upright, medium to moderately tall; shoots medium stout, moderately zigzag; internodes moderately short. Two-year bark greenish brown to moderately light brown; one-year bark yellowish brown; young shoots slightly reddish tinged; pubescence light to medium; lenticels few, small, flush, russet, not sharply defined. Growing tips reddish tinged. Petiole medium to moderately wide-angled, medium in length, moderately slender, reddish tinged. Leaf blade medium in size, roundish oval, very broad V-folded to slightly reverse saucer-folded, much reflexed; midrib distinctly raised; base rather full; apex moderately full; surface slightly rugose, glossy, medium to moderately dark yellowish green; margin even; serrations moderately coarse, very shallow to almost absent, serrate, moderately regular, often somewhat prominent on the older leaves.

19. Early Seckel. Habit rather upright, somewhat branchy, very short; shoots rather stout, typically fasciated and sometimes crooked; internodes mostly short but variable. Two-year bark dark reddish brown; one-year bark reddish brown to reddish; young shoots reddish tinged; pubescence medium; lenticels rather numerous, small, flush, somewhat whitish. Growing tips green. Petiole medium-angled, medium in length and thickness, green. Leaf blade moderately small, oval, flat to reverse saucer-folded, often reflexed; base moderately full; apex moderately full, reflexed; tip acute; surface smooth to slightly rugose or slightly bullate, with somewhat raised veins, semi-glossy, rather dark yellowish green; margin slightly coarsely waved; serrations coarse, moderately shallow, dull serrate, irregular.

20. Elizabeth. Habit upright-spreading, medium in height; shoots moderately slender, zigzag; internodes short. Two-year bark medium brown; one-year bark reddish brown; young shoots reddish tinged; pubescence medium (tendency to turn brown as tip matures); lenticels rather few, medium in size, mostly flush, russet, sometimes elongated. Growing tips pinkish tinged. Petiole medium-angled. moderately long, slender, pinkish tinged. Leaf blade medium in size, roundish oval to oval, medium to broad U-folded; base moderately full; apex full, often reflexed; tip mostly mucronate and distinct; surface somewhat rugose, moderately pubescent, moderately semi-glossy, moderately light to medium green; margin even; serrations medium in size, very shallow to absent, dull serrate, irregular.

21. Endicott. Habit spreading, branchy, rather short; shoots medium stout, somewhat zigzag; internodes short. Two-year bark rather dark grayish brown, somewhat greenish; one-year bark brownish green; young shoots green; pubescence light to medium, short; lenticels numerous, medium in size to moderately large, round, distinctly raised, russet. Growing tips green. Petiole medium-angled, short, medium thick, green. Leaf blade small, roundish oval, broad to medium U-folded, often twisted, upright; base rather full; apex moderately full; tip mucronate; surface very slightly bullate, slightly pubescent, semi-glossy to dull, medium green; margin even to slightly coarsely waved; serrations moderately fine, shallow, serrate, regular, sometimes very shallow and irregular. (The nursery trees at Amherst were propagated from wood taken from the original Endicott tree in Danvers, Massachusetts, supposedly planted about 1630 on the farm of Governor Endicott. Of no value as a fruiting variety, Endicott is included here because of its historical significance.)

22. Ewart. Habit spreading, rather branchy, medium in height; shoots rather stout, zigzag, very crooked; internodes short to medium. Two-year bark light grayish brown; one-year bark yellowish brown; young shoots green to dull reddish tinged; pubescence moderately heavy; lenticels medium in number and size, very slightly raised, russet. Growing tips reddish tinged. Petiole moderately narrow-angled, moderately short, medium thick, reddish tinged. Leaf blade medium in size, long oval to elliptic, medium to narrow U-folded; base and apex moderately full; tip acute; surface smooth, semi-glossy to moderately glossy, moderately light to medium yellowish green; margin even to very slightly waved; serrations medium in size and depth, sharply serrate, regular, rather prominent.

23. "False Bosc".* Habit upright-spreading, medium in height; shoots moderately stout, zigzag; internodes short. Two-year bark rather dark greenish brown; one-year bark light greenish brown; young shoots green; pubescence rather heavy, extending well down on the shoots; lenticels medium in number, large, flush, russet. Growing tips green to slightly pinkish tinged. Petiole narrow-angled, short, rather thick, green. Rather "leafy"; leaf blade medium in size, roundish oval, rather broad V-folded, upright, somewhat reflexed; base and apex full; tip mucronate and slightly reflexed; surface bullate, pubescent, moderately semi-glossy, light yellowish green, and mottled; margin even to slightly coarsely waved; serrations medium in size, variable in depth, sharply serrate, rather regular.

24. Flemish Beauty. Habit upright-spreading, medium in height; shoots slender, very slightly zigzag; internodes medium. Two-year bark rather dark brown, somewhat grayish; one-year bark reddish brown; young shoots reddish; pubescence medium; lenticels moderately few, small, flush, light russet. Growing tips reddish tinged. Petiole rather wide-angled, medium in length, slender, reddish tinged. Foliage rather sparse; leaf blade small, oval to elliptic, broad U to V-folded; base rather narrow; apex medium; tip acute to acuminate; surface smooth, semi-glossy to dull, medium green; margin mostly even; serrations moderately fine, shallow, serrate, regular.

25. Garber. Habit upright-spreading, tall; shoots medium stout, somewhat zigzag; internodes mostly long. Two-year bark brownish green and grayish; one-year bark brownish green; young shoots green; pubescence medium and short, rusty brown near tip; lenticels very numerous, medium in size, round, slightly raised, white, very conspicuous. Growing tips reddish tinged. Petiole rather narrow-angled but reflexed, rather short, rather thick, green. Foliage sparse; leaf blade large, long oval, flat to very broad V-folded, sometimes slightly reverse saucer-folded; base moderately full; apex rather narrow; tip acuminate, prominent, somewhat reflexed; surface moderately rugose, especially along the midrib, semi-glossy to dull, medium clear green; margin coarsely waved; serrations rather fine, rather shallow, sharply serrate, regular, prominent.

26. Gorham. Habit upright-spreading, branchy, medium in height; shoots moderately slender, moderately zigzag, slightly crooked; internodes short. Two-year bark moderately light to medium brown; one-year bark greenish brown tinged with red; young shoots reddish tinged; pubescence light; lenticels rather few, small, mostly round, flush, mostly russet. Growing tips reddish tinged. Petiole wide-angled, short, slender, reddish tinged. Rather "leafy"; leaf blade small, roundish oval, mostly saucer-folded; base and apex full; tip mucronate; surface mostly smooth, semi-glossy, medium yellowish green; margin even; serrations fine, medium in depth, serrate, regular, distinct.

---

*This is an unknown variety that has been found mixed with Bosc.

27. Hardy (Buerré Hardy). Habit upright-spreading, medium in height; shoots medium stout, zigzag, slightly crooked; internodes short. Two-year bark medium brown, slightly grayish; one-year bark reddish brown; young shoots reddish tinged; pubescence moderately heavy; lenticels moderately numerous, medium in size, round, flush, russet. Growing tips greenish to reddish tinged. Petiole medium-angled, short, medium thick, green. Leaf blade medium in size, oval, broad U- or V-folded, reflexed; base rather full; apex rather full, often reflexed; tip short, acuminate; surface smooth, with some evidence of large depressions, moderately semi-glossy, medium green; margin slightly coarsely waved; serrations medium in size, moderately shallow, rather dull serrate, somewhat irregular.

28. Howell. Habit upright-spreading, moderately tall; shoots moderately stout, zigzag; internodes medium. Two-year bark dull reddish brown; one-year bark light reddish to greenish brown; young shoots pink; pubescence medium; lenticels medium in number and size, round, flush, moderately whitish. Growing tips green. Petiole rather wide-angled, moderately long, medium thick, reddish tinged. Foliage sparse; leaf blade medium in size, long oval to elliptic, medium U-folded, somewhat reflexed, somewhat twisted; base rather narrow; apex moderately narrow, reflexed; tip sometimes upturned at the point; surface mostly smooth, somewhat pubescent, moderately dull, medium grayish (but rather clear) green; margin coarsely waved; serrations fine, shallow, sharply serrate, moderately regular.

29. Kieffer.* Habit upright, tall; shoots stout, slightly zigzag; internodes rather long. Two-year bark greenish to somewhat reddish brown; one-year bark greenish brown tinged with red; young shoots greenish brown; pubescence medium, short, rusty brown; lenticels moderately few to medium in number, medium in size, raised, slightly whitish. Growing tips dull reddish. Petiole moderately wide-angled, medium in length, thick, reddish tinged. Leaf blade large, oval, broad to medium U- or V-folded, upright, stiff; base rather full; apex moderately full; tip acute; surface smooth with net veins uniformly depressed, semi-glossy, rather dark green, sometimes slightly pubescent; margin somewhat coarsely waved; serrations medium in size, rather shallow, dull serrate, rather regular.

30. Koonce. Habit upright-spreading, tall; shoots medium stout, slightly zigzag; internodes medium. Two-year bark grayish brown tinged with red; one-year bark dull reddish brown; young shoots green to reddish tinged; pubescence rather heavy, extending well down on the shoots; lenticels medium in size and number, flush, whitish. Growing tips green to reddish tinged. Petiole medium-angled, moderately short, moderately slender, green. Leaf blade medium to rather small, rather long oval, flat to slightly reverse saucer-folded; base rather full; apex moderately full; tip long acute, twisted, reflexed; surface smooth to slightly rugose, with tendency for principal veins to be depressed, pubescent particularly on young leaves, semi-glossy, light to medium green; margin coarsely waved; serrations moderately fine, medium in depth, often setose-serrate, somewhat irregular, prominent.

31. Lawrence. Habit upright-spreading, medium in height; shoots moderately slender, straight; internodes short. Two-year bark moderately light to medium brown tinged with green; one-year bark slightly greenish to light brown; young shoots green; pubescence light; lenticels few, small, flush, somewhat whitish, rather conspicuous. Growing tips green to reddish tinged. Petiole very wide-angled, medium in length, rather slender, slightly reddish tinged. Leaf blade medium in size, oval, medium to narrow U-folded, somewhat reflexed; base moderately full; apex moderately full, slightly twisted; tip acute to acuminate but rather small; surface smooth, rather dull, medium to dark green; margin even to slightly coarsely waved; serrations medium in size and depth, serrate, somewhat irregular, distinct.

32. Lincoln. Habit spreading, rather tall; shoots moderately slender, moderately zigzag; internodes medium. Two-year bark light greenish brown; one-year bark green to light brownish; young shoots reddish tinged to reddish; pubescence medium; lenticels few to medium, medium in size, often elongated, flush, light russet. Growing tips green. Petiole wide-angled, moderately long, slender, reddish tinged. Foliage sparse; leaf blade moderately small, long oval to elliptic, mostly broad U-folded; base narrow; apex moderately narrow; tip acute, slightly twisted; surface mostly smooth, principal veins numerous, lightly pubescent, moderately semi-glossy, medium to rather light green; margin medium to coarsely waved; serrations medium in size, moderately deep, serrate, slightly hooked, somewhat irregular with a tendency to doubleness, prominent.

---

*From limited observation, nursery trees of the variety grown under the name Campas are very similar to, if not identical with those of Kieffer.

33. Lincoln Coreless. Habit upright-spreading, tall; shoots stout, straight to slightly zigzag; internodes medium. Two-year bark grayish brown; one-year bark green to slightly reddish to brown; young shoots pinkish tinged; pubescence light to medium; lenticels medium in number and size, round, slightly raised, russet to somewhat whitish, distinct. Growing tips reddish tinged. Petiole medium to wide-angled, moderately short and thick, green to reddish tinged. Rather "leafy"; leaf blade medium in size, oval, flat to very broad U- or V-folded, often twisted; base moderately full; apex moderately full, reflexed; surface usually smooth except for raised lateral veins, dull, medium to moderately dark green; margin even to slightly coarsely waved; serrations fine, moderately shallow, sharply serrate, regular, prominent.

34. Louise (Louise Bonne de Jersey). Habit moderately spreading, moderately tall; shoots rather slender, moderately straight; internodes medium. Two-year bark grayish green to greenish brown; one-year bark green to purplish brown; young shoots dull purplish; pubescence light to medium; lenticels medium in number and size, flush to slightly raised, mostly russet. Growing tips reddish tinged to reddish. Petiole medium-angled, rather short, medium thick, reddish tinged. Leaf blade moderately small, oval, sometimes broad but typically rather narrow U-folded, much reflexed, particularly at base of blade; base moderately full; apex moderately full, reflexed, slightly twisted; surface essentially smooth, semi-glossy, medium yellowish green; margin even to slightly coarsely waved; serrations rather coarse, medium deep, dull serrate, slightly hooked, rather regular.

35. Ovid. Habit upright-spreading, medium in height; shoots medium stout, somewhat zigzag; internodes rather long. Two-year bark slightly grayish green to greenish brown; one-year bark green to greenish brown; young shoots greenish to slightly reddish tinged; pubescence medium; lenticels rather numerous, rather small, round, slightly raised, russet with reddish margin. Growing tips reddish. Petiole wide-angled, rather short, medium thick, reddish tinged to reddish. Leaf blade rather large, roundish oval, broad U-folded, often reflexed; base and apex full; tip mostly mucronate, twisted; surface essentially smooth with occasional large depressions, semi-glossy to moderately dull, medium green; margin moderately coarsely waved; serrations moderately coarse, very shallow, serrate, irregular, indistinct especially on young leaves.

36. Parker. Habit upright-spreading, medium to rather tall; shoots medium stout, somewhat zigzag; internodes short. Two-year bark grayish brown; one-year bark slightly greenish to reddish brown; young shoots reddish tinged; pubescence light; lenticels medium in number, rather small, flush, moderately whitish. Growing tips reddish tinged. Petiole moderately wide-angled, medium in length, slender, reddish tinged. Leaf blade moderately small, oval to elliptic, mostly broad U-folded; base moderately narrow; apex moderately narrow, slightly reflexed; tip acute; surface smooth, rather dull, medium clear green; margin even; serrations rather fine, shallow, dull serrate, rather regular; many young leaves practically entire.

37. Patten. Habit upright, tall; shoots rather stout, slightly zigzag; internodes moderately long. Two-year bark purplish brown; one-year bark purplish; young shoots strongly reddish tinged; pubescence medium; lenticels medium in number, moderately large, often elongated, mostly flush, russet to whitish. Growing tips slightly reddish tinged. Petiole medium-angled, rather long, moderately slender, reddish tinged. Leaf blade moderately large, oval, broad U-folded, sometimes medium to narrow U-folded on upper parts of shoots, sometimes reflexed at base of blade; base full; apex moderately full, somewhat mucronate, slightly twisted, often reflexed; tip small acuminate; surface very finely bullate, moderately glossy, dark yellowish green; margin coarsely waved; serrations moderately fine, shallow, dull serrate, somewhat irregular.

38. Phelps. Habit moderately upright to spreading, rather tall; shoots moderately slender, zigzag, somewhat crooked; internodes medium. Two-year bark medium brown, slightly reddish tinged; one-year bark greenish brown; young shoots pink to slightly reddish; pubescence light; lenticels medium to moderately numerous, rather large, slightly raised, russet, rather conspicuous. Growing tips reddish tinged to reddish. Petiole medium-angled, short, moderately slender, green to reddish tinged. Foliage moderately sparse; leaf blade medium in size, ovate, medium U-folded; base rather full; apex moderately narrow, sometimes twisted; tip acute to somewhat mucronate; surface smooth, semi-glossy, dark yellowish green; margin even; serrations medium in size, very shallow, dull serrate, irregular, indistinct, some leaves entire.

39. Pulteney. Habit upright to slightly spreading, rather branchy, medium in height; shoots medium stout, slightly zigzag; internodes moderately short. Two-year bark medium brown; one-year bark yellowish brown; young shoots yellowish green to reddish tinged; pubescence medium; lenticels moderately few, moderately small to medium in size, often round, slightly raised, russet. Growing tips reddish. Petiole moderately wide-angled, moderately long, slender, reddish tinged. Leaf blade moderately small, moderately long oval to slightly obovate, broad to medium U-folded to slightly saucer-folded, with occasional twisted midrib; base medium; apex moderately full; tip mucronate, often twisted; surface smooth to slightly uneven, semi-glossy, medium yellowish green; margin mostly even; serrations medium, very shallow, serrate, irregular.

40. Seckel. Habit upright-spreading, rather short; shoots medium stout, slightly zigzag; internodes medium. Two-year bark rather dark brown; one-year bark greenish brown tinged with red; young shoots reddish tinged to slightly reddish; pubescence light; lenticels medium in number, small, flush, somewhat whitish. Growing tips reddish tinged. Petiole medium-angled, short, medium thick, green. Leaf blade medium in size, roundish oval, very broad V-folded to reverse saucer-folded, reflexed; base and apex full; surface fine textured, slightly rugose, glossy, moderately dark clear green; margin somewhat waved; serrations coarse, moderately shallow, dull serrate, slightly hooked, somewhat irregular.

41. Sheldon. Habit upright-spreading, medium in height; shoots medium stout, moderately zigzag; internodes short to medium. Two-year bark light to medium brown; one-year bark yellowish brown; young shoots yellowish green to slightly reddish tinged; pubescence moderately heavy; lenticels medium in number, rather small, flush, russet. Growing tips reddish tinged to slightly reddish. Petiole rather wide-angled, moderately long, rather slender, reddish tinged. Rather "leafy"; leaf blade moderately small, elliptic, broad to medium V-folded, midrib reflexed; base moderately narrow and rounded; apex narrow; tip acute to acuminate; surface essentially smooth, moderately semi-glossy, light yellowish green; margin coarsely waved; serrations medium to somewhat coarse, rather deep, serrate, slightly hooked, regular, prominent.

42. Vermont Beauty. Habit upright-spreading, medium in height; shoots rather slender, zigzag; internodes medium. Two-year bark rather dark brown; one-year bark dark reddish brown; young shoots reddish; pubescence rather light; lenticels medium in number, rather small, mostly flush, somewhat whitish, distinct. Growing tips green. Petiole wide-angled, long, moderately slender, reddish tinged. Foliage rather sparse; leaf blade small to medium in size, mostly elliptic, broad V-folded to broad U-folded, reflexed. spreading to drooping; base and apex narrow; tip mostly acute, sharp; surface smooth, rather fine textured, semi-glossy, medium green; margin even; serrations usually medium in size and moderately shallow, serrate, slightly hooked, rather irregular.

43. Waite. Habit mostly upright with a tendency for lower branches to start out at a wide angle, often branchy, medium or above in height; shoots medium stout, slightly zigzag; internodes short. Two-year bark brown to greenish brown and slightly grayish; one-year bark greenish brown; young shoots moderately reddish tinged; pubescence light; lenticels moderately numerous, small, moderately raised, russet. Growing tips reddish tinged to reddish. Petiole rather wide-angled, short, medium thick, reddish tinged. Rather "leafy"; leaf blade moderately small, oval to slightly roundish-oval, medium U-folded, with tendency to crooked midrib; base and apex moderately full; tip short, acute to mucronate, sometimes reflexed; surface smooth, dull to semi-glossy, medium yellowish green; margin mostly even; serrations variable in size and depth, serrate, often irregular.

44. Wilder. Habit upright, tall; shoots stout, mostly straight: internodes short. Two-year bark pinkish to reddish brown; one-year bark light reddish; young shoots pink; pubescence moderately heavy; lenticels medium in number and size, often elongated, mostly flush, russet. Growing tips green to pink or reddish tinged. Petiole narrow-angled, short, medium thick, green to reddish tinged. Rather "leafy"; leaf blade medium in size, oval to ovate, broad V-folded, reflexed at base of blade; base full; apex moderately full, sometimes twisted, reflexed; tip acute to acuminate; surface mostly smooth, dull to semi-glossy, rather light green, often "silvery" green; margin slightly coarsely waved; serrations moderately fine, medium in depth, serrate, regular.

45. Willard. Habit upright-spreading to spreading, medium to moderately tall; shoots medium stout, moderately zigzag; internodes medium to moderately long. Two-year bark greenish brown; one-year bark green to greenish brown; young shoots green; pubescence moderately light to medium; lenticels medium in number and size, mostly raised, somewhat whitish, rather conspicuous. Growing tips mostly green. Petiole medium-angled, medium in length and thickness, green to reddish tinged. Rather "leafy"; leaf blade rather large, ovate, flat to broad U- or saucer-folded, often reflexed; base full; apex moderately full, twisted; tip often slightly upcurved at the point; surface smooth except for raised veins and occasional rugoseness along the midrib, semi-glossy to moderately dull, dark clear green; margin mostly even; serrations fine, usually very shallow, dull serrate, moderately regular, younger leaves nearly entire.

46. Winter Nelis. Habit spreading, branchy, medium in height; shoots rather slender, moderately zigzag, often crooked; internodes medium. Two-year bark grayish brown; one-year bark greenish to yellowish brown; young shoots light reddish; pubescence light; lenticels rather numerous, moderately small, slightly raised, russet, often elongated laterally on 2-year bark. Growing tips red. Petiole wide-angled, medium in length, rather slender, reddish tinged. Leaf blade rather small, somewhat oval to elliptic, medium U-folded, moderately reflexed, slightly twisted; base and apex rather narrow; surface essentially smooth, semi-glossy, medium yellowish green with some mottling; margin even to slightly coarsely waved; serrations moderately fine, shallow to moderately deep, serrate, rather regular.

47. Worden Seckel. Habit upright-spreading, medium in height; shoots moderately slender, zigzag; internodes moderately short. Two-year bark greenish brown; one-year bark dark greenish to yellowish brown; young shoots somewhat reddish tinged; pubescence light; lenticels moderately numerous, small, flush, russet. Growing tips reddish tinged. Petiole moderately wide-angled, rather short, moderately slender, reddish tinged. Foliage rather sparse; leaf blade rather small, oval to ovate, flat to very broad V-folded; base moderately full; apex medium, slightly reflexed; tip acute; surface smooth, rather dull, moderately light yellowish green, usually mottled; margin even to slightly coarsely waved; serrations medium in size, shallow, dull serrate, somewhat irregular.

Literature Cited

1. French, A. P., Plant characters of cherry varieties. Mass. Agr. Expt. Sta. Bul. 401. 1943.
2. Hedrick, U. P., The Plums of New York, 1911. Albany.
3. Shaw, J. K., Leaf characters of apple varieties. Mass. Agr. Expt. Sta. Bul. 208. 1922.
4. Shaw, J. K., and A. P. French. The identification of apple varieties from non-bearing trees. Mass. Agr. Expt. Sta. Bul. 274. 1931.
5. Shaw, J. K., Descriptions of apple varieties. Mass. Agr. Expt. Sta. Bul. 403. 1943.
6. Shoemaker, J. S., Eliminating variety mixtures in nursery trees. Ohio State Hort. Soc. Proc. 60: 42-51. 1927.
7. Southwick, Lawrence, and A. P. French. The identification of plum varieties from non-bearing trees. Mass. Agr. Expt. Sta. Bul. 413. 1944.
8. Upshall, W. H., Nursery stock identification (plums, pears, peaches, cherries). Ontario Hort. Expt. Sta. Bul. 319. 1926.

Publication of this Document Approved by Commission on Administration and Finance
4M (c) 12-44-15376

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

AUG 13 1945

Bulletin No. 422 December, 1944

The Beach Plum in Massachusetts

By John S. Bailey

The beach plum industry on Cape Cod and the islands of Nantucket and Martha's Vineyard has developed to the point where there is a demand for improved plums and better methods for growing them. This bulletin reports work done to satisfy this demand.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE BEACH PLUM IN MASSACHUSETTS

By John S. Bailey[1]
Assistant Research Professor of Pomology

The beach plum (*Prunus maritima* Marsh.) is a wild native plum which grows in abundance along the beaches, among the sand dunes (Fig. 1), and on the coastal plains from Virginia to New Brunswick. It is very abundant on Cape Cod and the islands of Martha's Vineyard and Nantucket. Although it grows wild in these areas, it is by no means limited to them for it will thrive on inland soils as well. Several have been growing and fruiting at Amherst for a number of years.

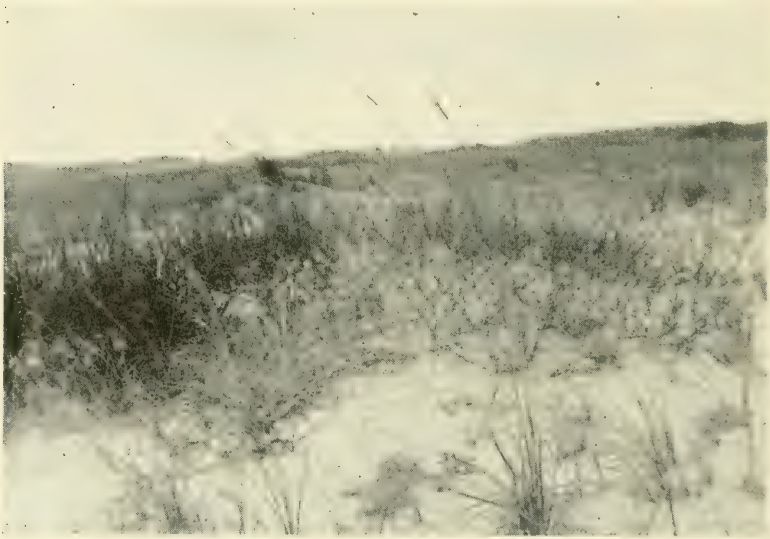


Figure 1. Typical Beach Plum Area.
The low-growing bushes can be seen mixed with the grass in the foreground.
Photo by Bertram Tomlinson.

The fruit of the beach plum has considerable economic importance (5) on Cape Cod, Martha's Vineyard, and Nantucket, where it is gathered for jelly and jam making. This industry has been developed until it is now on a commercial basis. However, the crop is uncertain, varying from almost no crop in some years to as high as 15,000 bushels in Barnstable, Dukes, and Nantucket counties in 1941. Prices have varied accordingly from $2.00 to a high of $6.20 per bushel. In 1941 beach plums were sold on the Boston retail market at 25 cents a quart during August and September.

Before the beach plum industry can expand, numerous problems of culture must be solved. Because of the variability of the fruit in jelly-making quality and of the bush in fruitfulness, there is a demand from those in the industry for a bush producing larger crops of better fruit. When improved bushes are obtained, better methods will be needed to propagate them. It will be important to know whether they grow best spaced in orchards and cared for like cultivated plums or allowed to cover whole areas as in the wild. Since they will probably benefit from the use of fertilizer, it is essential to know what kind and how much to apply. Ways must be found for controlling the numerous insects and diseases which ruin a large portion of each crop. Since a healthy and prosperous industry depends on good annual crops, the reasons for crop failures and ways to prevent them need to be found.

---

[1] The author wishes to thank especially Dr. C. E. Cross of the Cranberry Station, East Wareham, Massachusetts, for carrying out most of the field work. Thanks are also given to Mr. William Foster of Sandwich and the A. D. Makepeace Company of Wareham for the use of the beach plum property on which the experimental work was done; and to Mr. Bertram Tomlinson, County Agent of Barnstable County, Dr. H. J. Franklin, Cranberry Station, East Wareham, and many others who assisted with the work.

In order that something might be done toward the solution of these problems, the General Court in 1941 appropriated the sum of $500 for experimental work. This money together with the time of several research men and the facilities contributed by the Experiment Station allowed several projects to be started. This bulletin reports the results of the work undertaken and brings together such other information as should be useful to those interested in beach plum culture.

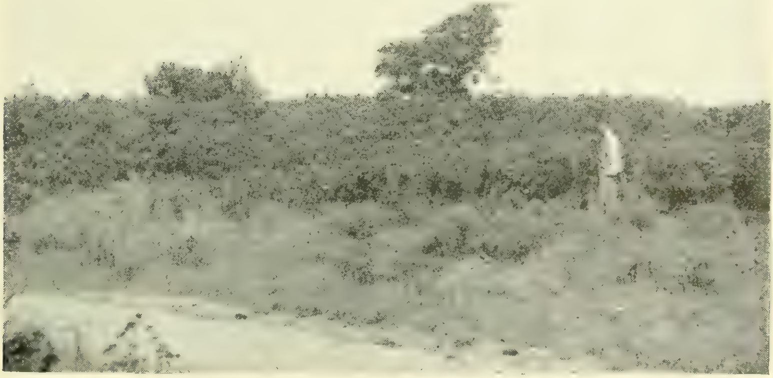


Figure 2. Thicket of Beach Plums — Tall, Erect Type.

Description

The beach plum is an exceedingly variable fruit. The range in vigor, size, growth habit, and fruitfulness of the bush and size, shape, color, and quality of the fruit is great because all wild plants are seedlings and, therefore, differ greatly in their hereditary makeup. Some bushes are dwarfish and recumbent with the lower branches lying on the ground, where they are often covered with sand; others are more tree-like, often 6–9 feet tall. The dwarf forms are usually spreading and send up many short vertical shoots 18–24 inches or more in length from the recumbent branches. They also sprout freely from the roots, so that a single bush may produce a veritable thicket 6–10 or more feet in diameter. The tree-like forms may grow singly or in groups, often so close together as to form thickets. (Fig. 2). In the areas where these plums grow may be found single bushes, small groups (Fig. 3), large groups (Fig. 4), or even large areas completely covered.

The root system is characterized by very few fibrous roots, a few large, coarse lateral roots which grow to considerable distances from the trunk, and a large, coarse taproot which grows deeply into the soil.

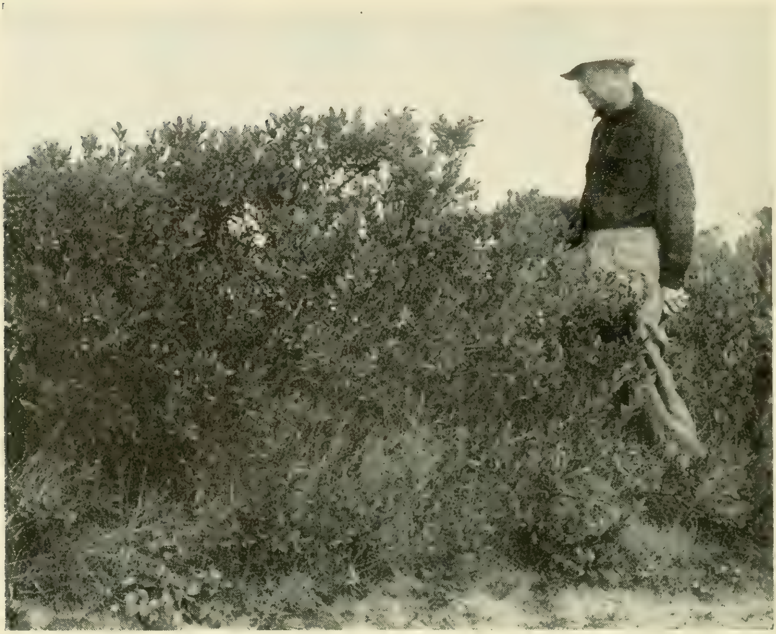


Figure 3. Typical Beach Plum Bush showing Fruit.

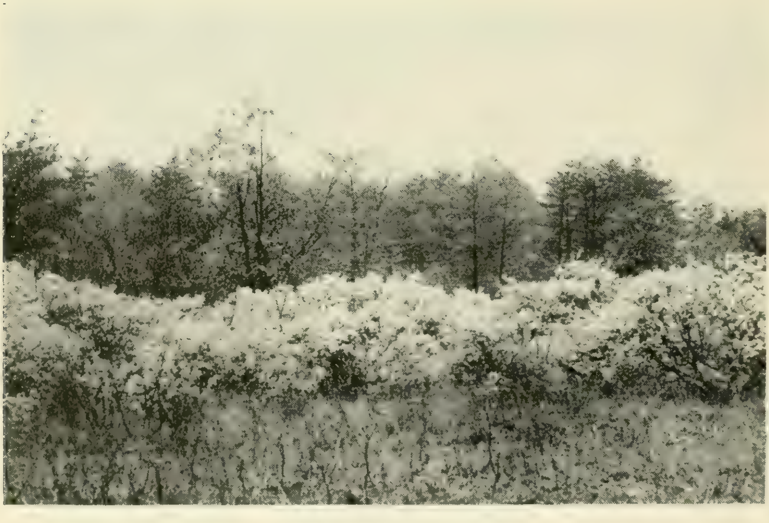


Figure 4. Group of Beach Plum Bushes in Bloom.

Photo by R. L. Coffin.

The leaves are ovate to elliptic, rather small, 1½ to 2½ inches in length, sharply pointed at the ends, sharply saw-toothed along the edges, dull green and smooth above, paler and softly hairy beneath, with rather stout, hairy stems 1½ to 2½ inches long, often with small glands on them. The flowers (Fig. 5), usually in clusters of 2 or 3, are white, small, ½ to 5/8 inch in diameter, with short stems about 3/16 inch long.

The fruit is usually about ½ inch across, but bushes have been found with fruit ¾ inch or more in diameter. The color varies usually from red through blue and purple to almost black, but occasionally bushes are found bearing yellow fruit. The surface of the fruit is covered with a white waxy bloom. The stone or pit is usually small and roundish, resembling a cherry pit in size and shape. In the few larger-fruited forms, the pit is bigger and more flattened and resembles a plum pit. The flavor varies from quite astringent and rather unpalatable to quite sweet and tasty. However, the beach plum is seldom eaten fresh. Its principal use is in the manufacture of jelly and jam. The fruits ripen from mid-August to the first of October.

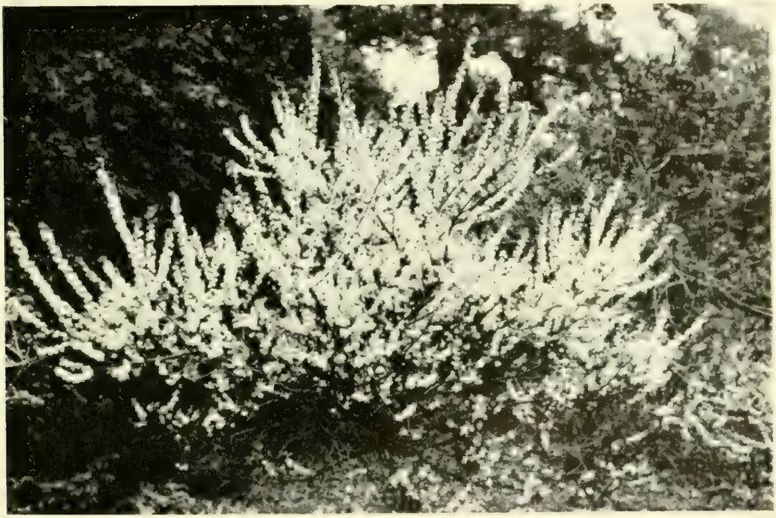


Figure 5. The Beach Plum Bush in Full Bloom is a Thing of Great Beauty — sometimes used as an ornamental.

Photo by R. L. Coffin.

Literature

The literature dealing with the beach plum is not so extensive as that dealing with other common fruits, yet it goes back into the writings of the earliest explorers to reach North America. Graves (4) has recently published an excellent history of the beach plum with an extensive bibliography. This history may be read to advantage by those interested.

Improvement

A number of people have observed for many years the beach plum bushes in their vicinity and selected superior bushes for future improvement work. Recently Mr. J. M. Batchelor, Associate Horticulturist of the Hill Culture Division of the Soil Conservation Service, searched over all the areas where beach plums grow and noted all the bushes selected by local observers. After careful evaluation, he selected several which he considered best. From among these, plants of five which seemed best adapted to Massachusetts conditions were planted at the Cranberry Station at East Wareham to be used for future improvement by breeding and selection.

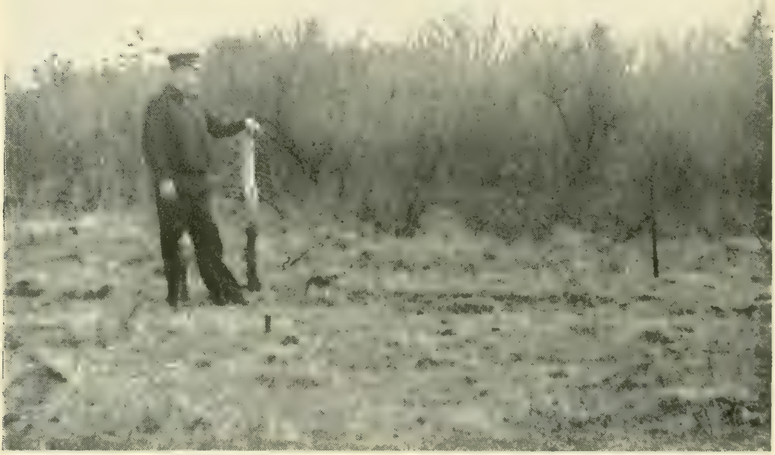


Figure 6. Old Beach Plum Bushes Before They Were Mowed to the Ground. There was much dead and diseased wood, and little growth was being made.
Photo by Bertram Tomlinson

Soils

The beach plum grows naturally in very light sandy soils, in many instances in almost pure beach sand. These soils are deficient in moisture and all the mineral nutrients necessary for normal plant growth. The ability of the beach plum to grow and fruit under such adverse conditions (conditions under which most plants cannot even survive) explains its natural distribution. It has little plant competition, such as has probably crowded it out of better soils.

On Cape Cod and the Islands of Martha's Vineyard and Nantucket, there are hundreds of acres of sandy soil suited only for the growing of beach plums. By improving this plum and developing suitable methods for its culture, these barren acres could be made to produce an income.

While the beach plum grows naturally only on the sandy soils in the southeastern part of the state, it is by no means limited to such areas. A number of bushes have been growing and fruiting at the College for several years. On the heavier, more fertile soils, they make a much more vigorous growth. There is some evidence, however, that overstimulation may result in winter injury.

Propagation

The beach plum can be propagated from seed. If the seeds are planted 3 or 4 inches deep in September, some will germinate and grow the following spring and some may take two years. Since beach plum seedlings, like those of other common fruit plants, will not be like the parent plant from which the seeds came, vegetative methods of propagation must be used if one wishes to obtain a number of plants from a desirable bush.

Many of our common fruits are propagated by grafting or budding the desired variety on a seedling root or stock. This can be done with beach plums. However, budding and grafting are slow, laborious methods which require considerable skill on the part of the operator. Both *Prunus americana* and *Prunus angustifolia* have been used as stocks. Since the latter species does not succeed north of its natural limit, which is in Delaware and Kentucky, its use as a stock in Massachusetts is questionable.

The use of cuttings offers a much more promising method of propagating beach plums. Graves (4) used root cuttings successfully. Pieces of root as big around as a lead pencil or larger were cut into 3 or 4 inch lengths and buried horizontally 2 or 3 inches deep in the soil out of doors in the fall. A heavy mulch was applied to keep the soil from heaving. This method should give a 50 percent stand of plants according to Graves.

Doran and Bailey (2, 3) had good success with softwood cuttings made in June and treated with a root-inducing substance. Best results were obtained with cuttings taken when the fruit was about 1/8 inch in diameter, treated with a powder dip of indolebutyric acid in talc, and placed in sand in a greenhouse bench where temperature and humidity could be controlled. Small side branches of the current season's growth 4 to 6 inches long rooted best. Untreated cuttings rooted very slowly or not at all.

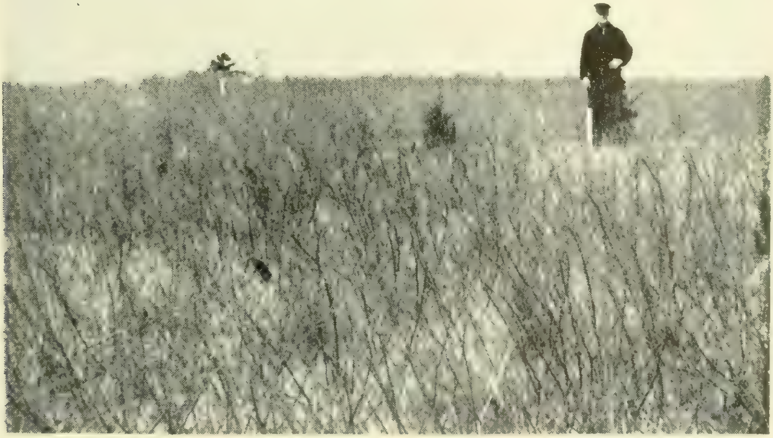


Figure 7. The Area Shown in Figure 6, a Few Years After It Was Mowed. Notice the vigorous growth of new wood from the old stumps.

Photo by Bertram Tomlinson.

Pruning

Pruning, like any other orchard practice, has as its ultimate objective the production of more and better fruit. This is accomplished by removing weak and dead wood, thus invigorating the remaining parts of the plant, and by removing diseased portions, thus assisting in disease control. It should be remembered that the stimulation resulting from pruning is temporary. To be maintained, it must be accompanied by fertilization of the soil.

In the case of young trees, pruning is used to assist the tree to develop a strong framework. Probably little can or need be done in this respect with young beach plum bushes.

The stimulating effect of pruning should be directed particularly at the portions of the tree which form the fruit buds. The beach plum forms its fruit buds on the current season's growth. Blooming and fruiting take place the following year. Therefore, pruning should be directed at producing the maximum number of vigorous new shoots annually as described below.

Beach plums are so variable in their growth habit that it is difficult to make pruning recommendations which will fit all cases. In a broad general way the bushes may be divided into two classes: (1) those which are low and spreading and sprout freely from the roots, thus making a thicket-like growth; and (2) those which have a tree-like form resembling cultivated plums in growth habit. It would probably not be economic to use conventional pruning methods on the first type of growth. Mowing with a brush scythe is certainly faster and, at least from what is now known, is fairly satisfactory (Fig. 6 and 7). However, growth following such treatment indicates that the stimulation is temporary. This method of pruning has the disadvantage that one or perhaps two crops are lost while the bushes are recovering. It is an established fact with other fruit plants that, while they need some pruning, yields are reduced in proportion to the increase in severity of pruning. There is no reason to think the beach plum is an exception.

With the more tree-like forms, it will probably pay in the long run to prune in the conventional way with shears and saw. First remove dead and weak wood. Then remove all black knot cankers or other diseased wood, making the cut several inches below the diseased portion. Finally, if the bushes are still very thick, remove a few of the old branches to make room for young vigorous growth. All prunings should be burned to destroy diseased portions.

Fertilization

Because beach plums are generally found on very poor soil, there has developed the general impression that they will not respond to fertilizer treatment; that they require a poor soil for their best development. If these notions are correct, the beach plum is indeed an unusual fruit. Certainly no one would expect any of the cultivated fruits to grow well and bear annual crops if they were continually starved. That the beach plums are usually in a state of starvation is indicated by the very small amount of growth that most bushes make. Also, the sandy soil, in many cases almost pure sand, in which they grow is known to be very deficient in all the chief fertilizer elements and may even be deficient in the trace elements.

To determine the effect of fertilizer, an experiment was started at Sandwich, Massachusetts, in 1942. Three plots 27′ x 35′ were laid out. One plot was given an application of 5-6-4 fertilizer on May 27 at the rate of 4000 pounds per acre. The second plot was given the same formula and the same amount but split into three applications, 100 pounds on May 27, 100 on June 10, and 200 on June 20. The third plot was left unfertilized.

Observations made on June 18, 1942, showed very little set on the unfertilized plot, a fair set on the plot with split fertilizer applications, and a very good set on the plot with a single application. This looks as if fertilizing beach plums would be worth while. A severe drought during the summer caused all the small fruits to shrivel and drop so that no yield records could be obtained. This drought turned what looked like a good beach plum year into one of almost total failure for the whole beach plum area.

In 1943 these three plots were again treated in the same fashion. A fourth plot was treated with cottonseed meal. Enough was applied to give 20 pounds per acre of nitrogen, equivalent to that in the 400 pounds per acre of 6-5-4. A second experiment was started in a beach plum planting near East Wareham, consisting of 5 rows of 10 bushes each set about 10 x 10 feet. Half the area was fertilized on May 17 with cottonseed meal to give 20 pounds of nitrogen per acre and half was left unfertilized. Since this area was covered with sod which seemed to be getting all the benefit from the fertilizer, a second and slightly heavier application was made to the fertilized half on June 10.

Again in 1943 the beach plum crop was nearly a total failure with a good crop in a few small isolated areas. Again the plots at Sandwich lost almost all of their fruit. There was a very light set on each of the fertilizer plots and the leaves of the bushes were a darker, richer green than those on the unfertilized plot. No fruit set on the unfertilized plot.

A total crop of 105 pounds of plums was harvested from the plots near East Wareham. Observations made during the summer indicated little, if any, difference in yield between the plots.

Since 400 pounds of 5-6-4 per acre, containing only 20 pounds of nitrogen, is a pretty light application, it is suggested that in the future enough fertilizer be applied to give 35 pounds of nitrogen per acre; for example, 500 pounds of a 7-7-7. A single application broadcast as growth starts seems best.

Pollination

It is a commonly expressed opinion among beach plum growers that the failure of crops is due to unfavorable weather at blooming time. It is true that weather at blossoming time has a marked effect on the set of any fruit. The effect may be direct by influencing the growth of the flowers or indirect by influencing the activity of pollinating insects and disease. A frost may destroy the blossoms. Cold, wet weather may prevent the shedding of pollen or, even though pollination has taken place, may so retard the growth of pollen tubes down the style that the ovule degenerates before fertilization takes place. On the other hand, pollination may be poor because pollinating insects either do not fly at all or are much less active during cold, rainy or windy weather. Also, rainy weather increases certain fungus diseases, particularly the blossom blight form of brown rot, which interfere with set. Nevertheless, such an obvious factor as the weather should not be blamed for every crop failure without just cause. In the same area, cultivated blueberries which bloom only a week or ten days later set good crops year after year. Because of the equalizing effect of the ocean on climate, it is unlikely that, in such a short time, the weather would change enough to repeatedly cause the failure of beach plums and have little or no effect on cultivated blueberries.

To study the relation of insects to crop success or failure, observations of the insects working beach plums and collections of these insects for identification were made at several places on the Cape during the blooming seasons of 1942, 1943, and 1944. Wild bees were found to be the most common pollinators, followed by bumblebees, syrphid flies, and some miscellaneous insects including a few honeybees. It was also observed that in some places there were very few insects, probably not enough to insure good pollination; while at other places on the same day plenty of insects were present. At one place, bumblebees were working apple blossoms in preference to beach plums although the beach plums were all around the apple tree and were in almost full bloom.

Insects

The beach plum is beset by a number of insects and diseases which, if not controlled, cut down the crop and detract from the value and appearance of the fruit. In the following descriptions only broad general control measures are given. For detailed instructions, see the spray chart on page 15.

The plum gouger (*Anthonomous scutellaris*) is undoubtedly the worst insect pest of the beach plum. The adult is a small dun-colored snout beetle less than 1/5 inch long, often described as looking like a baby elephant. The adults are said to come out of winter quarters early in the spring before the blossoms open and feed on the opening buds and leaves. Shortly after the fruit has set, the beetles feed on the pulp through small holes made in the skin. The female lays her eggs singly in cavities which she gouges in the fruit with her snout. When the eggs hatch, the larvae burrow into the pit where they feed on the kernel till full grown. The pupal stage is passed in the pit. Before changing to a pupa, the larva eats an exit hole through the hard shell of the pit to provide for the escape of the beetle. The adults emerge in late August or early September, eat little, and soon go into hibernation under trash in the vicinity. Infested fruits do not drop but ripen prematurely. The life history of this insect shows why, as has sometimes happened, the grower sells plums thinking there is nothing more wrong with them than a "sting" or two on the surface, and later the customer complains that the plums are wormy. Any grower who values his reputation must be careful about selling "stung" plums. Spraying before bloom has been the standard recommendation for control. However, experimental sprays of lead arsenate in 1942 and 1943 were not successful in controlling this pest.

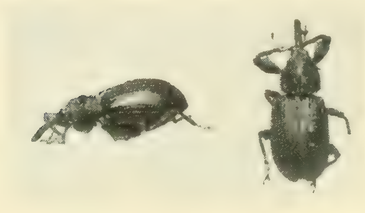


Figure 8. Plum Gouger.
Note smoothness of gouger's back in comparison with roughness of plum curculio.
Photo by R. L. Coffin.

The tent caterpillar (*Malacosoma americana*), a very common pest, is probably known by most growers. The eggs, which occur in brown masses, particularly on twigs of the wild cherry, hatch early in the spring when the first buds open. The young larvae, or caterpillars, soon make a silken nest in which they live in a colony and which they enlarge as they grow. They leave the nest to feed. They are very voracious eaters and will strip large branches or even whole trees of leaves in a short time if not controlled. The full-grown caterpillar is about two inches long, black with a light stripe down its back, and covered with fine yellow hairs. They are easily controlled by spraying or dusting with lead arsenate.

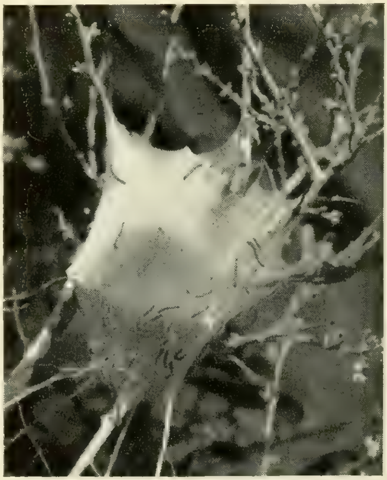


Figure 9. Tent Caterpillar's Nest on Beach Plum.
Photo by Bertram Tomlinson.

The plum curculio (*Conotrachelus nenuphar*) is a small snout beetle about 1/5 inch long, very closely resembling the plum gouger, but slightly larger. It can be distinguished from the plum gouger by the presence of humps on its back. Also, it can fold its snout back under its body, a trick the gouger cannot perform. The egg-laying punctures are quite distinctive. The gouger makes a single round hole; the curculio a hole with a crescent-shaped cut around it resembling a crescent and star, from which it gets the nickname "Little Turk." The curculio passes the winter in the adult stage under stones, leaves, and other plant debris. It comes out of hibernation about blossom time, somewhat later than the gouger, and becomes active about the time of the shuck spray or a little later, depending largely on temperature. If the temperature reaches 75° on two or three successive days at about shuck time, the curculio becomes very active.

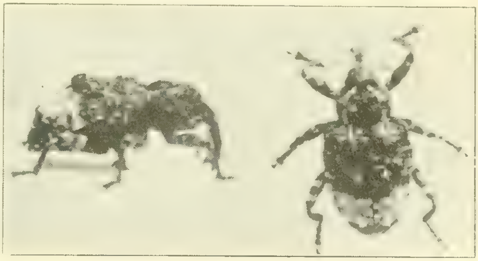


Figure 10. Plum Curculio Beetles.
Notice the pattern on the back, particularly the humps.

The female lays her eggs under the skin of the small fruits. The larvae hatch in about a week and feed on the flesh. Such infested fruits drop prematurely. After feeding in the plum about two weeks, the larvae leave and burrow into the soil where they pupate and change to the adult. Four weeks after the larvae enter the soil, the adults emerge with ravenous appetites. They usually lay no eggs but feed on the fruit until cold weather comes, when they hibernate. The curculio can be controlled by thorough applications of lead arsenate at the proper time.

Diseases

Plum pockets or plum bladders (Fig. 11) is probably the worst disease of beach plums. It is very troublesome in the coastal regions of the state where it attacks both wild and cultivated plums, and damage is often extremely heavy. It seldom appears in other parts of the state.

Plum pockets is caused by a fungus (*Taphrina pruni*) very similar in appearance and general behavior to that which causes peach leaf curl. It winters over in infected twigs. From these the fungus grows into the central part of the flower, the ovary, which later becomes the fruit. Some of the fungus threads grow to the surface of the twig and produce spore-forming bodies which discharge numerous spores. It also attacks young leaves causing them to curl, turn yellow, and drop. Infected plums become swollen, misshapen, and hollow, with no seeds; hence the name, plum bladders. Finally they turn dark brown or black and become hard so that they rattle against any hard surface. In this condition they hang to the tree only two or three days, then drop. This dropping takes place the latter part of June. This disease can be controlled by spraying with dormant-strength lime-sulfur. Where possible, diseased and dead twigs should be cut out and burned.

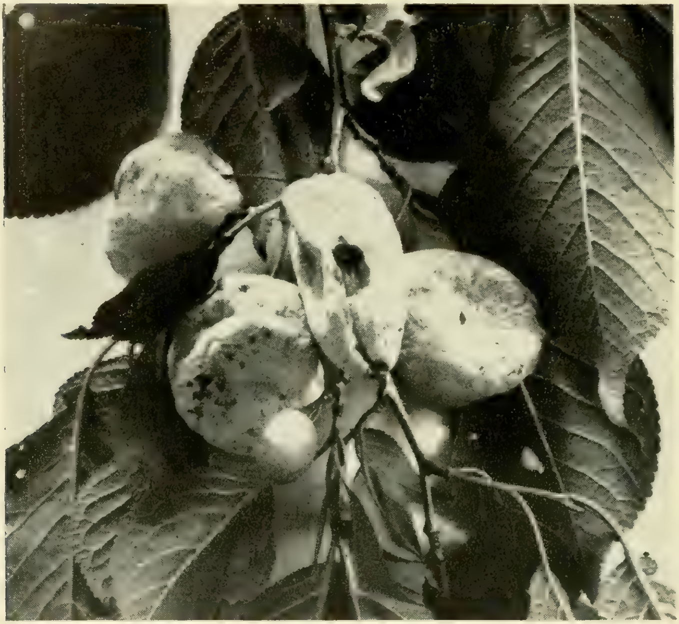


Figure 11. Plum Pockets or Plum Bladders.
Note large misshapen specimens, in comparison with healthy plum at lower left.
Photo courtesy of Plant Pathology Department, Cornell University.

Black knot, another common disease of beach plums, is caused by a fungus (*Plowrightia morbosa*). It develops in twigs and branches causing irregular knots which may become quite large. The surest method of control is to cut out and burn the knots. This should be done before January 1, since the winter spores are formed from January to June. Spraying also helps in its control.

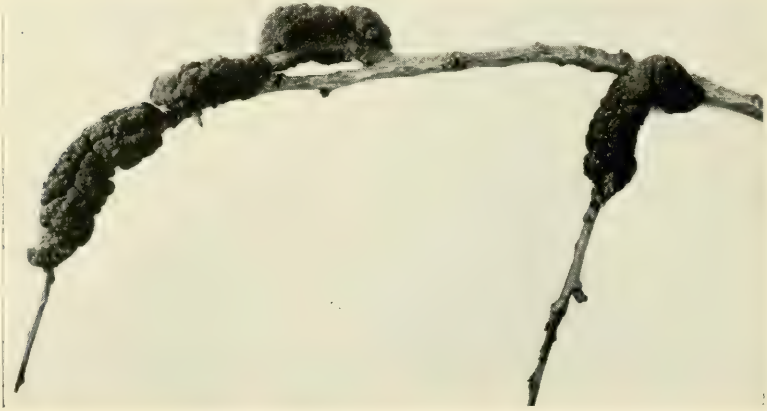


Figure 12. Black Knot Cankers on Plum Twig.

Brown rot, a very common disease of peaches, cherries, and plums, is caused by the fungus *Monilinia fructicola*, which sometimes causes severe loss in one of several ways. It may infect (1) the blossoms, preventing the set of fruit (called "blossom blight"); (2) the twigs (called "twig blight); (3) large limbs, causing cankers; or (4) green or ripe fruit, especially where it has been injured by insects, causing it to rot. These decayed fruits dry, shrivel, and become mummies covered with a gray mold from which spores are liberated to infect other fruits. Depending on conditions, these mummies may hang to the tree. In these mummies and in the limb cankers the fungus winters over. Brown rot is fairly easy to control by spraying thoroughly with wettable sulfur.

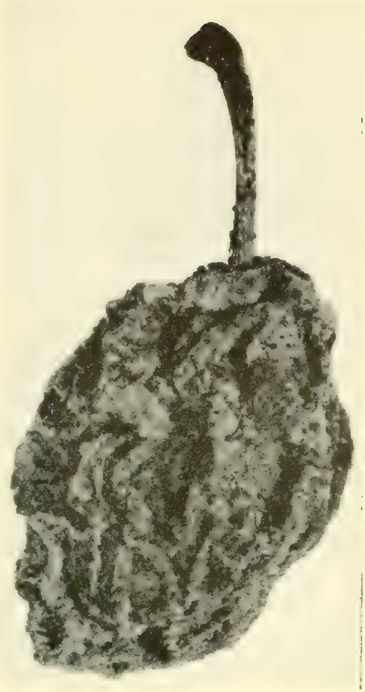


Figure 13. Typical Brown Rot Mummy of Plum
The disease lives over winter in these mummies and in limb cankers.

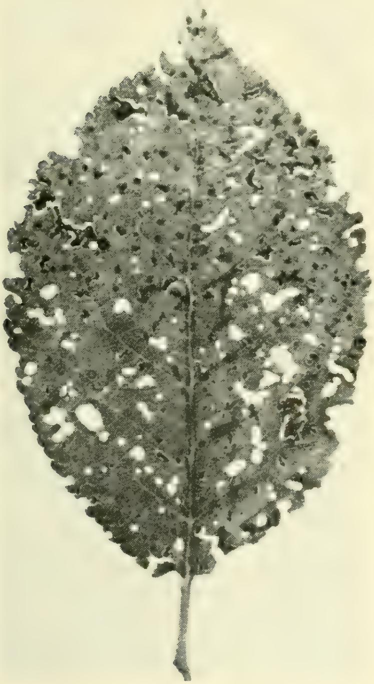


Figure 14. Leaves Affected with the Shot Hole Disease.
Photo courtesy of Plant Pathology Department, Cornell University.

Leaf spot, or shot hole, caused by the fungus *Coccomyces prunophorae*, is a very common disease of beach plums. It produces on the leaves round or irregular reddish or purplish spots which may turn brown and drop out, giving the leaves the appearance of having been peppered with shot. This disease ordinarily attacks the fruit very little. The damage to the leaves, which sometimes turn yellow and drop, may weaken the bushes to a considerable degree. It can be controlled by applying sulfur sprays.

Spraying

Experimental spraying was started in 1942 at Sandwich, Massachusetts. The spray schedule recommended by Tomlinson (5) was used, since it had never been tested experimentally to see whether adequate control was provided for all insects and diseases. Although a crop failure prevented close checking of results, observation indicated that (1) the plum gouger was poorly controlled, (2) a gall-maker, which was very common on the leaves of unsprayed bushes, was completely controlled, (3) plum pockets was not present in the sprayed area but was abundant on older adjacent unsprayed bushes, (4) brown rot was only fairly well controlled, some blossom blight being present on the sprayed plots in contrast to plenty of both blossom and twig blight in adjacent unsprayed areas. It was evident that modifications in the spray program must be made if good control of plum gouger and brown rot was to be obtained.

On the basis of the work of 1942, the following changes in the spray program were made: To control plum gouger — (1) Arsenate of lead was added to the Pre-blossom spray because the gouger is supposed to start its work before the blossoms open. In 1942, gougers were not found working until June 18 and in 1943 until June 17. (2) The amount of lead arsenate was increased from 3 to 4 pounds per hundred gallons whenever it was used. For better control of brown rot a fifth spray, the Second Cover, was applied 21 days after the Shuck. The lead arsenate in this spray should kill any gougers which might still be working on the plums.

In 1943, the experimental spraying was continued and expanded. A second experiment was started in the beach plum planting near East Wareham where the fertilizer work was done. Again in 1943 the crop was almost a total failure at Sandwich. What few plums matured were badly stung by gougers. Since there were so few plums, a very few gougers could have caused all the damage. On the plot near East Wareham, it was estimated that not over 10 percent of the fruit was stung by gougers.

The control of brown rot at East Wareham was excellent. At Sandwich, where control was not so good, brown rot was evident in the form of blossom blight. The presence of many blighted blossoms on unsprayed bushes next to the spray plot suggests that brown rot may be limiting the set of fruit by destroying the blossoms, thereby contributing in no small degree to the periodic crop failures. The difference in control at these two locations was due to difference in local conditions. The sprayed plot at Sandwich was surrounded on all sides by unsprayed bushes, some of them old and heavily infested with the pests. The plot near East Wareham was separated from the nearest unsprayed bushes by some distance. Although a strip 20 feet wide was sprayed around the plots, this was not wide enough at the Sandwich plot to keep pests from coming in from the unsprayed bushes. This is particularly true with regard to the plum gouger which is reported to be a very active flier.

As a result of the two years' experience, one more spray has been added to the 1943 schedule. This is a Petal Fall spray to be applied when 90 percent of the petals have fallen. It is intended to give better protection during the long period between the Pre-Blossom and Shuck sprays when leaves and fruit are developing very rapidly.

Spray Schedule for Beach Plums

When to Spray	What to Use (in 50 gallons)	To Control
1. **Spring Dormant** — before buds break.	Lime Sulfur (liquid 3½ gals. or dry 14 lb.)	Plum Pockets Black Knot
2. **Pre-Blossom** — just before blossoms open.	Lime Sulfur (liquid 1 gal. or dry 4 lb.) Lime 4 lb. (Note 1) Raw Linseed Oil or Fish Oil ½ pint (Note 2) Lead Arsenate 2 lb. (Note 3)	Plum Pockets Black Knot Tent Caterpillar
3. **Petal Fall** — when 90% of petals have fallen. (Note 4)	Wettable Sulfur (as recommended by manufacturer) Lime 4 lb. (Note 1) Raw Linseed Oil or Fish Oil ½ pint (Note 2) Lead Arsenate 2 lb. (Note 3)	Plum Pockets Black Knot Tent Caterpillar Leaf Spot Brown Rot
4. **Shuck** — as shucks fall.	Same as Petal Fall	Leaf Spot Curculio Brown Rot Plum Pockets Black Knot Tent Caterpillar
5. **First Cover** — 7 days after Shuck.	Same as Petal Fall	Leaf Spot Brown Rot Black Knot Curculio
6. **Second Cover** — 14 days after Shuck. (Note 5)	Wettable Sulfur (as recommended by manufacturer)	Leaf Spot Brown Rot

Note 1. Use only a freshly hydrated, 300-mesh, high-calcium (70% calcium oxide) lime.

Note 2. Directions for mixing: In a separate container, wet the lead arsenate to make a thick paste; add fish oil or raw linseed oil and stir to the consistency of paint: dilute with water and pour into tank.

Note 3. Always add lead arsenate last.

Note 4. To avoid the possibility of killing bees and other pollinating insects, do not apply this spray before 90% of the petals have fallen.

Note 5. To avoid residues of arsenic or lead above the federal tolerance, do not harvest sprayed fruit within six weeks after the last application.

Beach Plum Products

The experimental work on beach plum products was done in the Department of Food Technology and published by Davis and Levine (1). They came to the following conclusions: "A number of highly desirable products can be made from the beach plum. Among these the jam, jelly, and butter are the most popular. Generally the fruit is slightly deficient in pectin for jelly purposes, and addition of pectin was found necessary for the production of a high-grade jelly. No pectin is necessary for the jam or butter." However, they also state, "It is probable that under ideal conditions of maturity, satisfactory jellies for home use could be made without the addition of any substance to increase the jellying properties of the fruit."

Literature Cited

1. Davis, S. G., and Levine, A. S. Composition and utilization of the beach plum. Fruit Products Jour. 21:361-364. 1942.

2. Doran, W. L., and Bailey, J. S. Propagation of beach plums by softwood cuttings. American Nurseryman 76:7. 1942.

3. Doran, W. L., and Bailey, J. S. A second note on the propagation of beach plum by softwood cuttings. American Nurseryman 78:7-8. 1943.

4. Graves, G. The beach plum, its written record. Nat. Hort. Mag. 23:73-97. 1944.

5. Tomlinson, B. The culture of beach plums (*Prunus maritima*) in Massachusetts. Mass. Agr. Ext. Service Spec. Cir. 46. 1941.

Publication of this Document Approved by Commission on Administration and Finance
3M-4-45 16026.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

MAY 10 1945

Bulletin No. 423 December, 1944

Factors Affecting Annual Egg Production

By F. A. Hays

Modern methods of poultry breeding are based on specific characters that affect egg production. This study was undertaken for the purpose of developing more accurate methods of selecting birds for breeding purposes where the primary objective is increased egg production.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

FACTORS AFFECTING ANNUAL EGG PRODUCTION

By F. A. Hays and Ruby Sanborn

INTRODUCTION

Goodale (1918) first pointed out that annual egg production was dependent upon a considerable number of characters and stated that selective breeding should be based on this principle rather than upon gross annual egg records. Hays (1924) showed that a number of these characters were definitely inherited.

During the last 25 years the methods of poultry breeding have been greatly modified and improved so that the modern breeder selects and establishes specific characters that are known to affect annual egg production. The extensive literature concerned with modern poultry breeding is not reviewed here since this has been well done in the latest books on poultry breeding. Reference is made only to work having a particular bearing on the subject considered.

Character of Birds Used

The birds included in this study were all Rhode Island Reds that had been bred for many years for characters affecting egg production. The data were obtained from the first-year records of six generations of females hatched from 1937 to 1942 and included a total of 1470 birds. Only individuals with apparently normal annual trapnest records were included. This is the same population that was reported on in Bulletin 416 (Hays, 1944).

Object of Investigation

The study had one primary objective, which was to discover as many characters as possible that might affect annual egg production. The value of such information to the breeder lies in his ability to use such characters as units of selection in making up breeding pens.

The coefficient of correlation is probably the best measure of association where large samples are used. In this study the simple correlation was determined between sixteen independent variables, with the annual egg record as the dependent variable in all cases. The Blakeman test for linearity of regression was also applied.

RESULTS OF INVESTIGATION

Hatching Date

1. *Relation of Hatching Date to Annual Production*

Hatching dates ranged from March 6 to April 30 in the six-year period. During the first two years there were eight weekly hatches; in the next three years, seven weekly hatches; and in 1942, six weekly hatches. Annual egg records in all cases cover a period of 365 days beginning on the date the first pullet egg was laid. The simple correlation was determined between the hatching date and annual egg production, giving the following constants:

Number of birds	1470
Mean hatching date	April 1
Hatching date standard deviation—weeks	±1.87
Mean annual production—eggs	213.57
Annual production standard deviation	±43.38
Coefficient of correlation	+.0412±.0176

With the limited range in hatching date, there was no significant correlation between hatching date and annual production although regression was strictly linear.

Age and Weight at Sexual Maturity

2. *Relation of Age at First Egg to Annual Production*

Age at first egg has served for many years as a valuable unit in selecting for increased egg production. Dryden (1916) was one of the first workers to stress its value. Since the early 1920's early sexual maturity has been widely established in laying flocks. Hays (1924) showed that early sexual maturity is an inherited character and described its mode of inheritance. These observations have since been confirmed by other investigators, including Waters (1934) and Warren (1934). In breeding procedure one of the first steps is to fix genetic early sexual maturity in the flock.

The Rhode Island Reds used in this study bred true for early sexual maturity. There is, however, considerable variability in the age at first egg. By means of the coefficient of correlation it is possible to determine the relation of variability in age to annual egg production in a flock that breeds true for genetic early sexual maturity. The following constants appeared:

Number of birds	1470
Mean age at first egg—days	189.82
Age standard deviation	±16.43
Mean annual production—eggs	213.57
Annual production standard deviation	±43.38
Coefficient of correlation	−.1534±.0172
Correlation ratio	.2264

In this population breeding true for early sexual maturity there was a significant negative correlation between age at sexual maturity and annual production. Regression was found to be non-linear so that the correlation ratio .2264 expresses the association. This figure is in rather close agreement with the simple correlation values, ranging from −.24 to −.44, reported by Kempster (1925) for White Leghorns that did not breed true for early sexual maturity. These data show why selection for early sexual maturity has been effective in increasing annual egg production.

3. *Relation of Weight at First Egg to Annual Production*

The onset of sexual maturity initiates a new period in the life cycle of the bird. It has therefore been our regular practice to weigh each of the experimental pullets when she laid her first egg. It is also desirable to know whether body weight at this time is associated with subsequent annual production. The following constants were calculated:

Number of birds	1465
Mean weight at first egg—pounds	5.79
Weight standard deviation	±.54
Mean annual production—eggs	213.56
Annual production standard deviation	±43.33
Coefficient of correlation	−.1525±.0172

A mean weight of 5.79 pounds at sexual maturity indicates that the pullets used were large and that weight fluctuations were not very great at this time. Regression was linear and the negative correlation coefficient was only .1525. It is very probable that this correlation is brought about by age differences, as pointed out by Hays (1933).

Intensity

4. *Relation of Winter Clutch Size to Annual Production*

Winter intensity is one of the most useful tools in selective breeding, as pointed out by Hays (1944). Furthermore, birds lacking genetic high intensity averaged 31 fewer eggs in the first laying year than those exhibiting high intensity (Hays, 1944a). The coefficient of correlation, as previously reported for the same population (Hays, 1944), is repeated here with the constants found:

Number of birds	1470
Mean winter clutch size—eggs	3.23
Winter clutch size standard deviation	±1.42
Mean annual production—eggs	213.57
Annual production standard deviation	±43.38
Coefficient of correlation	+.5011 ±.0132
Correlation ratio	.5603

Regression was non-linear and the correlation ratio .5603 shows an intimate association between winter clutch size and annual production.

5. *Relation of Spring Clutch Size to Annual Production*

The mean spring clutch size was calculated for the months of March, April, and May and was tabulated against annual production, giving the following constants:

Number of birds	1467
Mean spring clutch size—eggs	4.04
Spring clutch size standard deviation	±2.44
Mean annual production—eggs	213.59
Annual production standard deviation	±43.40
Coefficient of correlation	+.4836 ±.0135
Correlation ratio	.6228

The mean spring clutch was larger and more variable than the winter clutch. This greater size is probably due to more nearly optimum weather conditions in March, April, and May. Regression of production on clutch size was non-linear, so the correlation ratio .6228 expresses the association. This is an intimate association and indicates that spring clutch size is a valuable criterion to use in the selection of yearling breeding females for high intensity.

6. *Relation of Summer Clutch Size to Annual Production*

The mean clutch size was calculated for June, July, and August to represent the summer period. These values were tabulated against the annual egg records, giving the following constants:

Number of birds	1456
Mean summer clutch size—eggs	3.06
Summer clutch size standard deviation	±1.68
Mean annual production—eggs	214.21
Annual production standard deviation	±42.95
Coefficient of correlation	+.5629 ±.0121
Correlation ratio	.6664

The mean rate of laying is lower in the summer months than in the winter and decidedly lower than in the spring. The standard deviation in summer clutch size is very large, indicating an extreme variability in the rate of laying. Regression was non-linear and the correlation ratio indicates a very important relationship between the rate of laying in summer and the annual egg production.

7. *Relation of Fall Clutch Size to Annual Production*

Fall clutch size was calculated for the months of September and October at the close of the first laying year. This constant should not be confused with the number of eggs laid during August and September as a measure of persistency suggested by Knox, Jull and Quinn (1935). Fall clutch size was tabulated against annual production to obtain the following constants:

Number of birds	1297
Mean fall clutch size—eggs	2.21
Fall clutch size standard deviation	±1.24
Mean annual production—eggs	218.83
Annual production standard deviation	±41.13
Coefficient of correlation	+.3063 ±.0170
Correlation ratio	.4122

The mean fall clutch size 2.21 indicates that the birds were laying at a slow rate toward the end of the year. It is believed, however, that rate of production near the end of the year is important. Regression was non-linear and the correlation ratio .4122 expresses the association. While rate of laying at the close of the year is less important than winter, spring, or summer rate, it does show a very significant correlation with annual egg production.

In general, the data on clutch size indicate that intensity of laying is intimately correlated with annual production. The importance of high intensity increases as the laying year advances to summer, so that rate of laying is more important in summer than at any other time of year.

Pause

8. *Relation of Winter Pause Duration to Annual Production*

Winter pause as used in these studies represents a cessation in egg production of eight or more successive days between November first and March first of the pullet laying year. The causes of winter pause are known to be both genetic and environmental. In this experiment attempts have been made to keep environmental conditions as constant as possible but unsatisfactory laying houses limited the possibilities. The duration of pause was tabulated against the annual production, using only birds exhibiting pause, and gave the following constants:

Number of birds with winter pause	721
Mean winter pause—days	36.47
Winter pause standard deviation	±19.90
Mean annual production—eggs	196.73
Annual production standard deviation	±40.06
Coefficient of correlation	−.2565 ±.0235

In the total population, 721 birds, or 49 percent, exhibited winter pause. The duration of the pause was extremely variable, with a mean of about 36 days. Mean egg production was relatively low for the pause birds — about 33 eggs below that of the non-pause group. Regression was linear, and a significant negative correlation appears between pause duration and annual production.

9. *Relation of Spring Pause Duration to Annual Production*

Pauses of eight or more days during March, April, and May may be classified as spring pauses. They have been little studied, probably because most hens lay particularly well at this time. In this population 356 hens exhibited a spring pause. These have been tabulated to discover the correlation between spring pause duration and annual production. The following values appeared:

Number of birds with spring pause	356
Mean spring pause—days	26.21
Spring pause standard deviation	±26.61
Mean annual production—eggs	184.42
Annual production standard deviation	±41.77
Coefficient of correlation	−.3323 ±.0318
Correlation ratio	.4088

The birds exhibiting spring pause were relatively low producers, with an average of about 184 eggs. Another very striking fact is the immense variability in spring pause duration. There is the suggestion that pathological conditions may have produced many spring pauses, but there is no proof of this. A further possibility might be physiological disturbances in some of the birds.

Regression was non-linear, so that the correlation ratio .4088 expresses the association. The magnitude of this constant shows that the length of the spring pause is rather intimately associated with annual egg production and that it has a somewhat greater effect than was observed for winter pause.

10. *Relation of Summer Pause Duration to Annual Production*

Summer pauses of eight or more days, not associated with broody behavior, often occur in June, July, and August. Such pauses are of much more frequent occurrence than spring pauses. In the population studied 749 individuals exhibited summer pause. The possible association between the duration of summer pauses and annual egg production in the summer pause population has been studied. The following constants appeared:

Number of birds with summer pause	749
Mean summer pause—days	40.64
Summer pause standard deviation	±31.32
Mean annual production—eggs	196.02
Annual production standard deviation	±41.47
Coefficient of correlation	−.4629 ±.0194
Correlation ratio	.4966

There was a marked variability in the duration of summer pause. In this group of birds production was mediocre, but superior to that of birds with spring pause. Regression was non-linear, so the correlation ratio expresses the association, which was more intimate than was observed for either winter or spring pause.

The duration of pauses in production in winter and in spring were about equally important in relation to annual egg production. The variability in duration of summer pause was more intimately correlated with annual production. On the whole, these periods of non-production deserve very careful consideration.

Broodiness

11. *Relation of Number of Broody Periods to Annual Production*

In the population of 1470 females, only 56 individuals or 3.8 percent exhibited broody behavior during the first laying year. This group of 56 birds had a mean annual egg production of 212.18 eggs compared with an average of 213.62 eggs for the 1414 non-broody individuals. The average number of broody periods for the broody population was 1.39 or the equivalent of about 21 productive days lost for each individual. The broody population was shown to be superior to the non-broody population in winter intensity. The respective clutch sizes were 3.81 and 3.20 days (Hays, 1944).

In the attempt to discover whether there was a significant correlation between the number of broody periods and annual production in the small broody population, the following constants appeared:

Number of broody birds	56
Mean number of broody periods	1.36
Number of broody periods standard deviation	±.72
Mean annual production—eggs	212.18
Annual production standard deviation	±30.12
Coefficient of correlation	+.0009±.0901

The above data indicate that there was no correlation between the number of broody periods and annual egg production in the small population studied.

Persistency

12. *Relation of Annual Persistency and Annual Production*

The work of many investigators has shown that persistency is one of the most important characters affecting egg production. The term "persistency" as used in this laboratory is concerned entirely with the length of the pullet laying year. Biologically, persistency is circumscribed by sexual maturity at the beginning of the year and by annual molt at the end of the year. It is our belief that persistency is independent of the rate of laying. The population was tabulated, giving the following constants:

Number of birds	1470
Mean annual persistency—days	338.33
Annual persistency standard deviation	±37.58
Mean annual production—eggs	213.57
Annual production standard deviation	±43.38
Coefficient of correlation	+.4704±.0137
Correlation ratio	.5194

Since the regression was non-linear, the correlation ratio correctly measures the association, which is a very intimate one and indicates that high persistency is an extremely important character in its relation to annual egg production.

Egg Weight

13. *Relation of Time to Standard Egg Weight to Annual Production*

The time to standard egg weight is measured by the number of days required from the first pullet egg to the period in which a pullet lays five successive 56.7-gram or two-ounce eggs. It is conceivable that a very rapid increase in egg weight might reduce the number of eggs laid and that a slow rate of increase in egg weight might be associated with a greater number of eggs. Records were secured on 1150 individual birds and the correlation was determined between this time interval and annual egg production. The following constants appeared:

Number of birds	1150
Mean time to standard egg weight—days	49.70
Time to standard egg weight standard deviation	±49.10
Mean annual production—eggs	212.73
Annual production standard deviation	±43.29
Coefficient of correlation	+.0476±.0198
Correlation ratio	.2111

The time required to attain standard egg weight was extremely variable. The mean period was about fifty days, which we believe to be about normal for a high-producing flock carrying the inheritance for large egg size. Regression was not linear, and the correlation ratio .2111 indicates that the time required to attain standard egg weight does affect annual egg production in a positive manner.

14. *Relation Between March Egg Weight and Annual Production*

Hays (1944b) showed that egg weight during the month of March is one of the most valuable measures of egg weight that may be employed. Results of investigations of the relation of egg weight to number of eggs laid are not entirely consistent. It is conceivable, therefore, that egg size may be one of the factors that affect annual egg production. The following constants were calculated:

Number of birds	612
Mean March egg weight—grams	60.54
March egg weight standard deviation	±3.95
Mean annual production—eggs	213.67
Annual production standard deviation	±42.29
Coefficient of correlation	−.0048±.0273
Correlation ratio	.1707

March egg-weight records were available on 612 females and showed a mean of 60.54 grams (25.7 ounces to the dozen). This mean showed that the birds carried genes for large egg size even though a considerable proportion lacked genetic purity. Regression of annual production on March egg weight was not linear. The correlation ratio .1707 measures the association, which is negative. In other words, heavy egg weight in March has a significant tendency to be accompanied by fewer eggs for the first laying year.

15. *Relation of Annual Egg Weight to Annual Production*

This relationship has already been reported for the same population in Bulletin 416 (Hays, 1944). In this study regression was non-linear and the correlation ratio between annual egg weight and annual egg production was .2297. This constant was of a positive order, indicating that annual egg weight and annual production tended to increase together.

In general, time required to attain standard egg weight, mean March egg weight, and annual egg weight all have significant effects on annual egg production. Although these relations are not intimate, they must be considered in a program of breeding to increase egg production.

Body Weight

16. *Relation Between Body Weight at the End of the First Laying Year and Annual Production*

Individual body weights were taken when the birds in the house had been laying for about twelve months. It is desirable to know whether body weight at that time showed any association with previous annual egg production. The following constants were calculated:

Number of birds	1340
Mean body weight at end of year—pounds	5.97
Body weight standard deviation	±.77
Mean annual production—eggs	214.31
Annual production standard deviation	±43.30
Coefficient of correlation	−.0486±.0184
Correlation ratio	.2183

Considerable variability was noted in the body weight of the birds and the mean was below the 6.5 pounds stipulated by the American Standard of Perfection. Regression was non-linear so that the correlation ratio .2183 expresses the association. This is of a negative order and indicates that heavy body weight at the close of the year is likely to be associated with lower antecedent egg production.

Simple Regression Coefficients

Because of the large number of characters included in this study, it was not considered expedient to spend the vast amount of labor necessary to calculate the partial and multiple coefficients of correlation. As a partial substitute, the simple regression coefficients are presented for each of the sixteen variables. The regression coefficients in this summary measure the rate of change in annual egg production with respect to a unit change in each individual character. It is recognized that there is considerable overlapping between these characters and that the partial regression coefficients would differ from the simple regression coefficients. It is believed, however, that the values presented furnish reasonably safe guides for breeding operations.

The mean values for the sixteen different characters as far as known in 1916 furnish a starting point. Any differences between these initial means and the means of the birds used in this study represent either progress or retrogression. Table 1 presents the difference between the mean of 1916 and the mean of the present population, the simple regression coefficient of annual egg production on the particular character, and finally the expected increase or decrease in annual egg production.

TABLE 1.—CHANGES IN MEANS, REGRESSION COEFFICIENTS, AND EXPECTED CHANGES IN EGG PRODUCTION.

Character		Change in Mean	Regression Coefficient	Expected Increase or Decrease in Egg Production
Hatching date	weeks	−2.	+.957	−1.91
Age at first egg	days	−40.	−.598	+23.91
Weight at first egg	pounds	−.28	−12.200	+3.42
Winter clutch size	eggs	+.73	+17.155	+12.52
Spring clutch size	eggs	+.46	+11.082	+5.10
Summer clutch size	eggs	+.13	+16.993	+2.21
Fall clutch size	eggs	+.05	+13.676	+.68
Winter pause duration	days	+2.88	−.516	−1.49
Spring pause duration	days	−9.15	−.642	+5.87
Summer pause duration	days	−1.82	−.657	+1.20
Number of broody periods		−2.14	+.037	−.08
Annual persistency	days	+90.80	+.600	+54.44
Time to standard egg weight	days	−57.23	+.186	−10.65
March egg weight	grams	+4.24	−1.826	−7.74
Annual egg weight	grams	+4.01	+2.569	+10.30
Weight at end of laying year	pounds	−.35	−12.229	+4.28
Total increase				+102.06

The second column of the table records the change in means between that of the flock hatched in 1916 and the population hatched from 1927 to 1942 and used in this study. In the case of egg weight and time to standard egg weight, the earliest records were taken on the 1927 flock and this mean had to be used as a starting point.

Some significant changes in means may be observed. Hatching date has been changed to two weeks earlier in the recent flocks and this is a handicap as far as annual egg production is concerned. Age at first egg has been reduced 40 days and this favors increased egg production. Body weight at first egg has been decreased about .28 pound largely because of earlier sexual maturity. Intensity has been greatly improved in winter, as clutch size shows. Spring intensity has been somewhat increased, but summer and fall intensity show little improvement. Pause duration has increased slightly in birds exhibiting winter pause. There has been considerable reduction in the length of spring pauses but only a slight reduction in length of summer pause. The number of broody periods has greatly declined in the few birds that exhibit broodiness. Annual persistency shows a remarkable increase of almost 91 days. Time from first egg to standard egg weight has declined almost two months. Egg weight in March and egg weight for the entire first year have increased by about 4 grams for each egg, about 14 percent. This is equivalent to an increase of about 1.7 ounces to the dozen. Body weight at the end of the first laying year has declined about .35 pound.

Regression coefficients in the third column of the table record the rate of change in egg production associated with unit changes in each character.

The figures in the last column of the table were obtained by multiplication of columns two and three. For example, hatching date has been changed to two weeks earlier than it was in 1916. Since early hatching tends to reduce annual egg production, we should expect that change to reduce the mean annual egg record slightly. The table shows an expected reduction of 1.91 eggs. Other changes in means that would be expected to be accompanied by a decrease in annual egg production were winter pause duration, number of broody periods, time to standard egg weight, and March egg weight. Winter pause duration probably had little effect because there was a tendency for the percentage of birds with winter pause to decrease. The percentage of birds exhibiting broodiness was so small that any change in the number of broody periods would have little effect on the flock as a whole.

A number of changes in means have had a very significant effect in increasing the annual egg record. Among these are age at first egg, winter clutch size, annual persistency, and probably annual egg weight. There was very little change in such characters as summer and fall clutch size, spring and summer pause duration, and body weight at the end of the laying year.

An examination of the size of the regression coefficients indicates that intensity as measured by clutch size at different seasons of the year is extremely important. Since summer and fall clutch size did not change significantly between 1916 and the recent period, it seems very probable that these two should be given special attention if egg production is to be increased. Spring pause and summer pause are not very important, yet they too should be considered in selective breeding. Egg size in the population studied has attained a satisfactory level with the average time required to reach a 24-ounce level about 50 days, and the mean annual egg weight was 58.51 grams or 24.8 ounces to the dozen. Very likely body weight at the close of the first laying year should not be further reduced.

When the combined estimated effects of these sixteen characters is summed up at the bottom of the fourth column, an approximation of what the mean egg record of the 1937 to 1942 flocks should be is arrived at. The mean annual egg record of the 1916 flock was 134 eggs (Hays and Sanborn, 1939). The mean annual record of the 1470 birds hatched from 1937 to 1942 was about 214 eggs. Adding the expected increase of 102 eggs to the original 134 gives a value of 236. Thus the actual average production lacks 22 eggs of expectation. It is interesting to note that the flock hatched in 1942 averaged to lay 233 eggs.

In general, the data in table 1 emphasize the need of increasing the intensity in spring, summer, and fall. To a lesser extent the shortening of spring and summer pauses offers opportunities. Since the present level of egg size is satisfactory, no change in this character would seem to be desirable. From the standpoint of selective breeding, it seems desirable to add the following to the list for selective purposes: High spring, summer, and fall intensity and short spring and summer pauses.

SUMMARY

An attempt has been made to measure the effects of sixteen factors on annual egg production. The study included records on 1470 Rhode Island Red females bred for high fecundity and hatched from 1937 to 1942. The following deductions seem to be warranted.

1. Hatching date within the range used showed no significant correlation with annual egg production.

2. Annual production exhibited a non-linear regression on age at sexual maturity. The association was negative, with a correlation of .2264.

3. Body weight at first egg showed a small but significant negative correlation with annual production.

4. High winter intensity as measured by clutch size had an intimate association with annual production, although regression was not strictly linear; high spring intensity was slightly more intimately associated with annual production than winter intensity, regression again being non-linear; and summer clutch size was more important than either winter or spring clutch size as measured by the correlation ratio with annual egg record. Clutch size was least important in the fall, but its relation to annual egg production was still very significant.

5. Duration of winter pause, in the part of the population having winter pause, showed an important negative correlation with annual egg production; spring pause duration was of greater importance than winter pause duration; and summer pause duration was more intimately negatively correlated with annual production than pauses in either winter or spring.

6. There was no correlation between the number of broody periods and annual production in the small population of broody birds.

7. Annual persistency was intimately associated with yearly egg production.

8. There was a moderate positive association between time to standard egg weight and annual production.

9. Larger egg weight in March had a significant tendency to reduce the number of eggs laid in the year; but a moderate positive correlation showed that annual egg weight and annual egg production tended to increase together.

10. There was a moderate negative correlation between body weight at the close of the first laying year and annual production.

11. The data indicate that, among the different characters studied in relation to egg production, intensity of laying in summer and fall offer good possibilities in selection. Pauses in production in winter, spring, and summer should also be carefully selected against in breeding stock.

12. Evidence is submitted to indicate that the sixteen different characters considered offer a very good working basis upon which to direct future breeding operations.

REFERENCES

Dryden, James. 1916. Poultry Breeding and Management. p. 132. Orange Judd Co., New York.

Goodale, H. D. 1918. Internal factors influencing egg production in the Rhode Island Red breed of domestic fowl. Am. Nat. 52: 65-94; 209-232; 301-321.

Hays, F. A. 1924. Inbreeding the Rhode Island Red fowl with special reference to winter egg production. Am. Nat. 58: 43-59.

Hays, F. A. 1933. Relation between body weight and age at sexual maturity. Poultry Sci. 12 (1): 23-25.

Hays, F. A. 1944. Relation of intensity to egg weight and egg production. Mass. Agr. Exp. Sta. Bul. 416.

Hays, F. A. 1944a. The significance of inherited characters affecting egg production. Poultry Sci. 23 (4): 310-313.

Hays, F. A. 1944b. Variability in egg weight in Rhode Island Reds. Mass. Agr. Exp. Sta. Bul. 411.

Hays, F. A. and Ruby Sanborn. 1939. Breeding for egg production. Mass. Agr. Exp. Sta. Bul. 307 revised.

Kempster, H. L. 1925. The correlation between sexual maturity and egg production. Mo. Agr. Exp. Sta. Res. Bul. 78.

Knox, C. W., M. A. Jull and J. P. Quinn. 1935. Correlation studies of egg production and possible genetic interpretations. Jour. Agr. Res. 50 (7): 573-589.

Warren, D. C. 1934. Inheritance of age at sexual maturity in the domestic fowl. Genetics 19: 600.

Waters, N. F. 1934. Growth and sexual maturity in Brahma and Leghorn fowls. Iowa State College Jour. Sci. 8: 367.

Publication of this Document Approved by Commission on Administration and Finance
5M-1-45-15566

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 424 APRIL, 1945

The Culture of Set Onions in the Connecticut Valley

By W. G. Colby, C. J. Gilgut, and H. M. Yegian

The weather conditions peculiar to the Connecticut Valley and cultural practices influenced thereby have a definite effect on the yield, appearance, and keeping quality of onions. These practices and their influence are discussed here.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE CULTURE OF SET ONIONS IN THE CONNECTICUT VALLEY

W. G. Colby,[1] C. J. Gilgut,[2] and H. M. Yegian[3]

CONTENTS

	Page
Factors affecting the yield of set onions:	
Soils	2
Seed bed preparation	2
Cover crops	3
Fertilization and liming	4
Varieties of set onions	5
Cultural practices	5
Factors affecting losses from disease:	
Weather	9
The quality of seed sets	9
Soil	11
Crop rotation	12
Fertilizers	12
Time of harvest	13
Methods of harvesting and curing	13
Storage conditions	14
Summary	15
Literature cited	16

Onion growing is an important, long-established agricultural enterprise in the Connecticut Valley of Massachusetts. At first most of the commercial crop was grown from seed, but the acreage of seed onions is now relatively small, and the greater part of the crop is obtained from set onions. The purpose of this bulletin is not to discuss in detail the growing of set onions—years of experience have already made the Connecticut Valley onion grower proficient in the art of onion culture; but rather to discuss some of its more troublesome aspects in the light of recently concluded experiments.

FACTORS AFFECTING THE YIELD OF SET ONIONS

Soils

Connecticut Valley onions are grown almost entirely on fine or very fine sandy loam soils. These are deep soils, well-drained and fairly retentive of moisture, and workable soon after the frost is out of the ground. The latter point is important because the onion is essentially a cool season crop and early planting is a necessary factor in securing high yields. Set onions can probably be grown more satisfactorily on light soils than seed onions since the growing season of the former is shorter and they reach maturity before the hot dry weather of late July and August.

Seed Bed Preparation

Most growers prefer to plow their onion land in the fall because it facilitates early spring planting operations. There is also a prevailing opinion among growers that fall-plowed lands maintain better moisture relationships during summer dry periods and that they tend to blow less during the period between planting of the bulb and the time top growth is heavy enough to afford protection from the wind.

Just as soon as the soil can be worked in the spring, it is thoroughly disced and then harrowed, first with an Acme and then with a Meeker harrow, until a finely pulverized seed bed with a smooth level surface is secured.

---

[1] Research Professor of Agronomy.

[2] Research Assistant in Botany; now Assistant Research Professor of Nurseryculture.

[3] Research Assistant in Agronomy.

The authors are grateful to the following onion growers for their wholehearted cooperation in the conduct of field experimental work: Arthur Hubbard, Walter Hubbard, Clarence Clark, and Michael Skibiski, all of Sunderland.

Some difficulty may be experienced from using tractors in preparing onion land. With a tractor, as the soil is worked following fertilizer application, the fitting harrow tends to concentrate the fertilizer in the two trenches left by the rear wheels, occasionally resulting in some injury to the crop. The possibility of trouble can be reduced to a minimum if lightweight tractors are used for the final fitting operation and if repeated working of the soil after fertilization is avoided.

Cover Crops

Anyone who has witnessed dust storms in the Connecticut Valley during the winter and early spring months will agree that winter cover crops should be grown more extensively than they are. While cover crops will not eliminate all blowing of the soil, particularly in the spring, the use of good sod-forming cover crops will markedly reduce wind erosion. The difficulty is that the onion crop is one of those for which an entirely practical system of cover cropping has not yet been worked out. Because of their earlier maturity, set onions can be followed with a cover crop more satisfactorily than seed onions; but difficulties of a practical nature still exist in disposing of a winter cover in the spring.

If suitable cover crops are to be fully effective in curtailing wind and water erosion and in accomplishing all the other beneficial effects ascribed to them, they should remain on the land over the winter. But such a practice requires spring plowing, and, as has already been explained, spring plowing for onions tends to delay planting and is not generally favored. It has been suggested that this objection be met by plowing in the late summer after the onions have been harvested and seeding with a non-winter-hardy cover crop such as oats or barley. The following spring the winterkilled remains could be taken care of with a thorough discing in the process of seed bed preparation. The practicability of such a plan will depend upon whether or not a cover which is heavy enough to be effective can be disposed of in this way so that it will not interfere with the planting and cultivation of the onions which follow.

If the cover crop is plowed under in the late fall, there is no interference with spring planting but some of its effectiveness is lost. Nevertheless, such a practice is a great improvement over no protection whatsoever, and in recent years many growers have sown cover crops on onion land and have handled them in this manner. Results from trials carried on in 1941 with different cover crops indicate that some are more valuable than others. Oats, domestic or common rye grass, Italian rye grass, field brome grass, and buckwheat were all seeded on August 12 following the harvesting of a crop of set onions. Excellent growth was made on all plots both with and without additional fertilization. On October 21 all plots were plowed. Dry matter yields of the tops of the different crops used are shown in the following table.

TABLE 1.—DRY MATTER YIELDS OF COVER CROPS FOLLOWING SET ONIONS

Type of Cover Crop	Yield of Dry Matter (Lb. per Acre)	
	No Nitrogen	150 lb. Calcium Cyanamid
Oats	2900	3480
Domestic Rye Grass	2975	3050
Italian Rye Grass	3125	3340
Field Brome Grass (*Bromus arvensis*)	2250	2030
Buckwheat	1810	....

The rye grasses developed a heavy sod which was clearly distinguishable up until the time the land was disced the following spring. It was evident that this sod, even though plowed, had been effective in reducing water erosion and probably wind erosion also. The field brome grass formed a heavy, resistant sod but was in no way superior to either of the rye grasses. Oats developed a rather loose sod which disintegrated rapidly; and buckwheat, of course, formed no sod at all. It would seem that in rye grass a cover crop is available which exerts a protective influence throughout the winter and spring even though it is plowed late the preceding fall. It is a crop which is already being used extensively as a winter cover following many other crops.

The use of nitrogen fertilizer to stimulate growth of cover crops is questionable in the average season on most onion land. There is usually enough residual fertility in the soil to support near optimum growth, but there may be situations, particularly following wet growing seasons when most of the nitrates have been lost through leaching, where the application of additional nitrogen on the cover crop may be justified.

Fertilization and Liming

Liberal use of complete fertilizers, broadcast in the spring, has long characterized Connecticut Valley onion culture. The application rate of 2000 to 3000 pounds per acre and the grades commonly used have not changed greatly for some time. There has been a trend toward higher concentration of some elements, particularly nitrogen and to some extent potash. For example, the minimum nitrogen content is now 5 percent instead of 4 percent. The fertilizer grades most commonly used include 5-8-7, 5-10-5, and 5-10-10. As yet, the use of double strength fertilizer has been limited, although some 8-16-16 and 8-16-8 have been used.

An abundant supply of available calcium in the soil is necessary for the vigorous healthy growth of onions. Since practically all onion soils tend to become depleted in available calcium from year to year, and therefore more acid in reaction, it is necessary to replenish the calcium supply by occasional liming. Frequent light applications of limestone are more desirable than infrequent heavy ones. Most growers recognize this fact by applying a ton or more of limestone to their onion land regularly every three to four years. The optimum soil reaction for onions is about pH 6.0 to pH 6.5.

The common practice in fertilizer application is to broadcast all of it prior to planting. In 1941 an experiment was carried out in which the fertilizer application was split, part being plowed under in the early spring and part being broadcast just before planting. Of a total application of 2250 pounds of a 5-8-7 fertilizer, 1800 pounds were plowed under and 450 pounds were broadcast after plowing. This method of fertilization was compared with another application of 2250 pounds of the same formula applied in the usual manner. There were no significant differences in top growth, quality, and yield of onions between the plots where the fertilizer was all broadcast on the surface and where part of it was plowed under.

Accumulated evidence indicates that the maximum rate of 3000 pounds per acre should be reduced to 2500 pounds or less when a 5-10-10, 5-10-5, or 5-8-7 fertilizer is used. Heavy applications of fertilizer may cause serious injury, not only immediately after planting but also later in the season, particularly during dry seasons. Quite frequently in the middle of the growing season growth is retarded and the tips of the leaves in some fields die back for two or three inches. That the trouble is due to fertilizer injury is shown by the following facts:

1. It is most prevalent on light soils which have been heavily fertilized;
2. Measurements of the soluble salt concentration of the soil have shown concentrations to be much higher where the trouble occurs, frequently double that of soils where the growth is normal;
3. It appears following a period of weather which is characterized by light showers of varying frequency, but no heavy rains;
4. Invariably the trouble disappears following a heavy leaching rain.

Obviously, if 3000 pounds per acre causes trouble, topdressing with more fertilizer, as is sometimes done, will only aggravate the trouble. In most cases injury will be avoided if maximum rates are kept under 2500 pounds to the acre of a single-strength fertilizer or its equivalent.

Varieties of Set Onions

Most of the set onions grown in the Connecticut Valley are of the Ebenezer variety, commonly called the Japanese. This onion produces a semi-flattened bulb of good size, with a medium yellow skin. The crop matures early; yields are usually good; and if the small sets are properly graded as to size, few "bolters" or seed stalks are formed. When the crop is grown and harvested under favorable conditions, it usually keeps well in storage.

During recent years an increasing acreage of Globe onions has been grown from sets. These have been sold under several varietal names, including Golden Globe, Golden Marvel, Connecticut Yellow Globe and just Yellow Globe. In general, Globe onions have a round bulb with a heavy yellow skin. Ordinarily they mature a few days later than Ebenezer onions.

The Globe varieties have become increasingly popular because of their high yielding capacity and excellent keeping quality. When satisfactory growing and harvesting conditions prevail, Globe sets will usually outyield Ebenezer sets and keep better in storage. However, if weather conditions are not favorable, particularly as the crop approaches maturity, both the yield and the keeping quality of a Globe crop are apt to be disappointing. The proportion of immature, oblong "bottleneck" bulbs varying greatly in size is often large; and such bulbs not only spoil the appearance of the crop, but also keep poorly in storage.

In general, returns from Ebenezer sets are quite consistently satisfactory. Although returns from Globe sets may be greater in some years, the risks involved are also greater.

Cultural Practices

For many years all operations in the planting, cultivating, and harvesting of onions were performed by hand. The labor requirement for growing an acre of onions was high but the cash return was also high and, since labor was plentiful, little attention was given to labor-saving methods. In recent years, market prices have been less favorable and labor less plentiful and more expensive than formerly. As a result, the large growers, and many of the smaller ones, have endeavored to reduce labor requirements by the use of machines wherever possible. Machines for planting small sets are in general use and small garden tractors are becoming more popular.

Machine methods have introduced some problems which did not exist when only hand methods were employed. It is with these problems in mind that the following operations of planting and growing are discussed.

Planting.—Machine Versus Hand Setting. The methods used in planting sets have been found to materially affect the yield of onions. Hand planting, although slow and laborious, nevertheless results in the largest yields. Machine planting, in which a set planter distributes the sets along one or two rows, is much faster and also easier, but yields are invariably lower.

In a trial conducted in 1941, a relatively dry season, machine-planted sets yielded at a rate of 500 fifty-pound bags of onions to the acre as compared with 760 bags from hand-planted sets. The lower yields from machine-planted sets are largely due to the failure of set planters to space the sets evenly in the row and to place them uniformly in an upright position. The importance of placing sets in an upright or nearly upright position is shown by the results of another experiment carried on in the same year. Sets which were all planted horizontally yielded 75 percent as much as sets which were all set upright, while sets which were completely inverted yielded only 20 percent as much.

The subsequent sprouting and establishment of sets dropped at random by a machine varies, of course, with the weather conditions immediately after planting. If the weather is dry, reductions in yield may be considerable; but if sufficient moisture is present, a good crop may result even if some sets are not placed in proper position.

Most growers who use the machine planters follow the machine with a crew who properly space the sets, removing excess sets where bunched and filling in spaces missed. The use of carefully graded sets when machines are used, a practice adopted by the large growers, improves the planting accuracy of the machines.

The power planter, particularly in times of labor shortage, is a great help to the grower with a large onion acreage. One man with a modern two-row planter can cover five or more acres in a day compared with only one acre planted by about 10 hand workers. The greater speed of the machine planters also enables the grower to get his sets planted quickly whenever the changeable April and early May weather permits. Most significant is the lower cost of machine planting, an important factor for large growers who have to hire all their labor. The savings in production costs more than offset the loss from reduced yields.

TABLE 2.—EFFECT OF SET SIZES ON YIELD PER ACRE (1941).

Sets spaced 13.8″ between rows, 2.25″ in the row.

Size of Sets		Yield — 50 lb. Bags per Acre
Small (Oats)	¼″ to 3/8″	560
Regular	½″ to 3/4″	750
Oversize	¾″ to 7/8″	890

Rate of Planting.—The number of bushels of sets required to plant an acre is determined by the size of the sets used, the distance between the rows, and the spacing of the sets in the rows. Long experience has shown that sets ranging from ½ inch to ¾ inch in diameter are ideal for planting. If sets less than 3/8 inch ("oats") are used, the yield is usually reduced; if sets larger than ¾ inch are grown, the percentage of "bolters" or bulbs producing seed stalks is invariably high. Here again, weather conditions may materially influence the performance of both undersize and oversize sets. In years when the supply is short, sets from

⅜ inch to 1 inch are frequently used; when sets are plentiful, only the optimum sizes are used. Notwithstanding the fact that large sets produce many bolters, they are often planted because they mature early and the grower may take advantage of early-season prices. As set size increases, yield per acre also rises (as shown in Table 2); but it should be borne in mind that when larger sets are used the number of bushels required to plant an acre increases sharply (see Table 5).

It has been customary to space onion rows 12 to 13 inches apart. With the advent of power machines for onion culture, it was found necessary to increase the width between rows to at least 14 inches in order to prevent injury to roots and tops and to better control weeds. Table 3 gives the yields of mature onions from rows of varying widths.

TABLE 3.—EFFECT OF VARYING THE DISTANCE BETWEEN ROWS ON YIELDS OF MATURE ONIONS.

Sets of ½″ to ¾″ size, spaced 2.25″ apart in the row.

Distance Between Rows	Yield — 50 lb Bags per Acre	
	1940	1941
12 inches	615	–
13 inches	630	740
14 inches	569	600

The usual practice is to plant the small sets 2¼ inches apart, measured center to center, in the row. An experiment was conducted for three years to determine the effect on yield of different spacing in the rows. While yields from close spacing were much greater, the percentage of small bulbs ("picklers") was high and the number of sets required per acre was large (Table 4).

TABLE 4.—EFFECT OF SPACING IN THE ROW ON YIELD OF MATURE BULBS.

Sets of ½″ to ¾″ size, spaced 13.8″ between the rows.

Spacing in Row	Yield 50 lb. Bags per Acre		
	1940	1941	1942
Close, 1½″	740	680	810
Normal, 2¼″	670	575	660
Wide, 3½″	550	510	520

Careful measurements of set sizes from random samplings were compiled in Table 5 to show the approximate number of bushels of sets of different sizes required to plant an acre at varying distances apart between the rows and in the rows.

TABLE 5.—BUSHELS OF DIFFERENT SIZE SETS REQUIRED TO PLANT AN ACRE AT VARYING DISTANCES BETWEEN THE ROWS AND IN THE ROW.

Size of Sets	Bushels Required to Plant an Acre								
	12″ Rows			14″ Rows			16″ Rows		
	Spacing in Row			Spacing in Row			Spacing in Row		
	2.5″	3.0″	3.5″	2.5″	3.0″	3.5″	2.5″	3.0″	3.5″
1/2 inch......	21.0	17.5	15.0	18.0	15.0	13.0	16.0	13.5	11.5
5/8 inch......	34.0	28.0	24.0	29.0	24.0	20.5	25.5	21.0	18.0
3/4 inch......	56.0	46.5	40.0	48.0	40.0	34.5	42.0	35.0	30.0
7/8 inch......	75.5	65.5	56.0	68.0	56.0	48.0	58.5	49.0	42.0
1 inch..........	112.5	94.0	80.5	96.5	80.5	69.0	84.5	70.5	60.5

Cultivation and Weeding.—Keeping a field free of weeds is one of the most important and also one of the most expensive operations in the growing of a crop. It has been estimated that cultivating and weeding make up nearly 40 percent of the total labor cost (1). Because of the small, shallow root system and the upright growth habit and round structure of the onion leaves, which provide relatively little shade, the plant is a poor competitor against weeds. If weeds are not kept in check, yields are low, harvesting is difficult and costly, and losses from rots are usually large both in the field and in storage. While the principal objective of cultivation is to control weeds, many growers feel that frequent stirring of the ground, particularly after heavy rain, is also beneficial to growth.

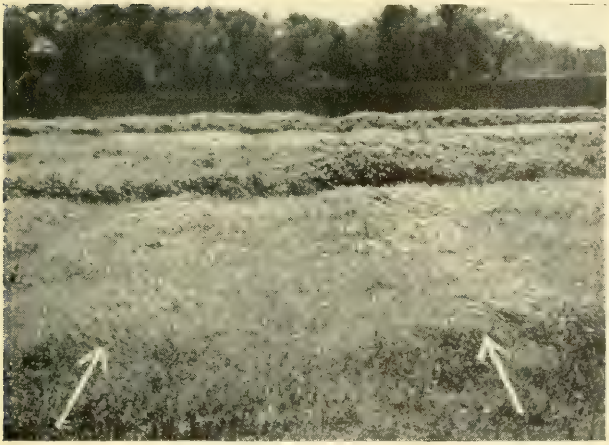
As a rule, onion fields in the Connecticut Valley in the past were well cared for during the growing season. Much of the crop's success can be credited to this one fact alone. The farmers who actually tended the crop were willing to hand cultivate with wheel and "shove" hoes six to eight times during the season and to perform the arduous, time-consuming task of carefully removing the remaining weeds from each row by hand.

Many growers with small acreages will continue to grow their onions in this manner, for in this way they are able to get maximum acre yields. Rows are planted close together and, if care is exercised in cultivating, little injury is done to the onion plant. Large growers, on the other hand, are willing to accept less than maximum acre yields if they can use small tractors for at least part of their cultivation and thereby reduce production costs. When tractors are used, however, rows must be spaced further apart, with 14-inch rows as a minimum.

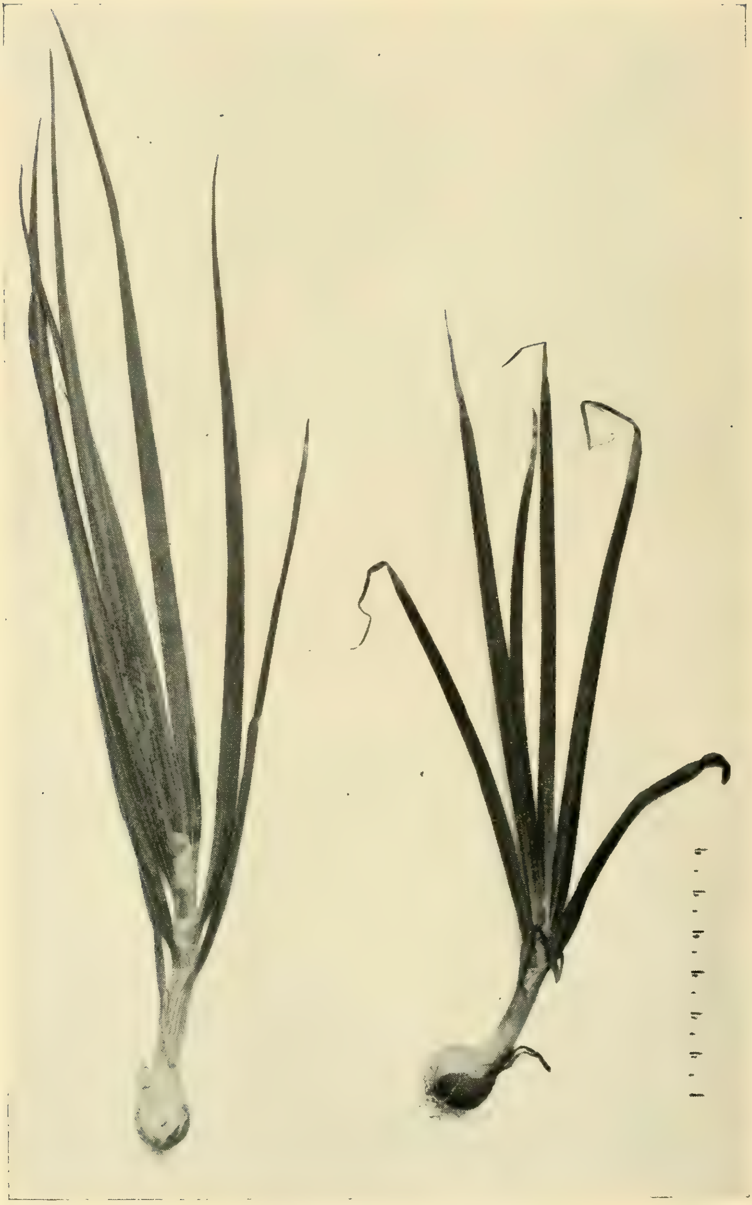
Tractor cultivation has proved satisfactory during the early part of the growing season, but as the crop develops increasing care must be exercised. The root system of the onion is not extensive, and serious injury to any part of it will be reflected in reduced vigor and growth of the plant. The roots grow out laterally from the base of the bulb for several inches before they turn down. It is easy to see how the passage of garden tractor wheels between narrow rows might result in serious injury to the plant after the lateral roots have developed. This in turn would result in reduced yields. It is also obvious why frequent shallow cultivations are to be preferred to less frequent deep ones.

After the crop is well along, some hand cultivation and hand weeding is usually necessary to supplement the use of tractors. It is doubtful if an onion crop can be entirely grown with tractor cultivation as long as the practice of planting in narrow rows is adhered to.

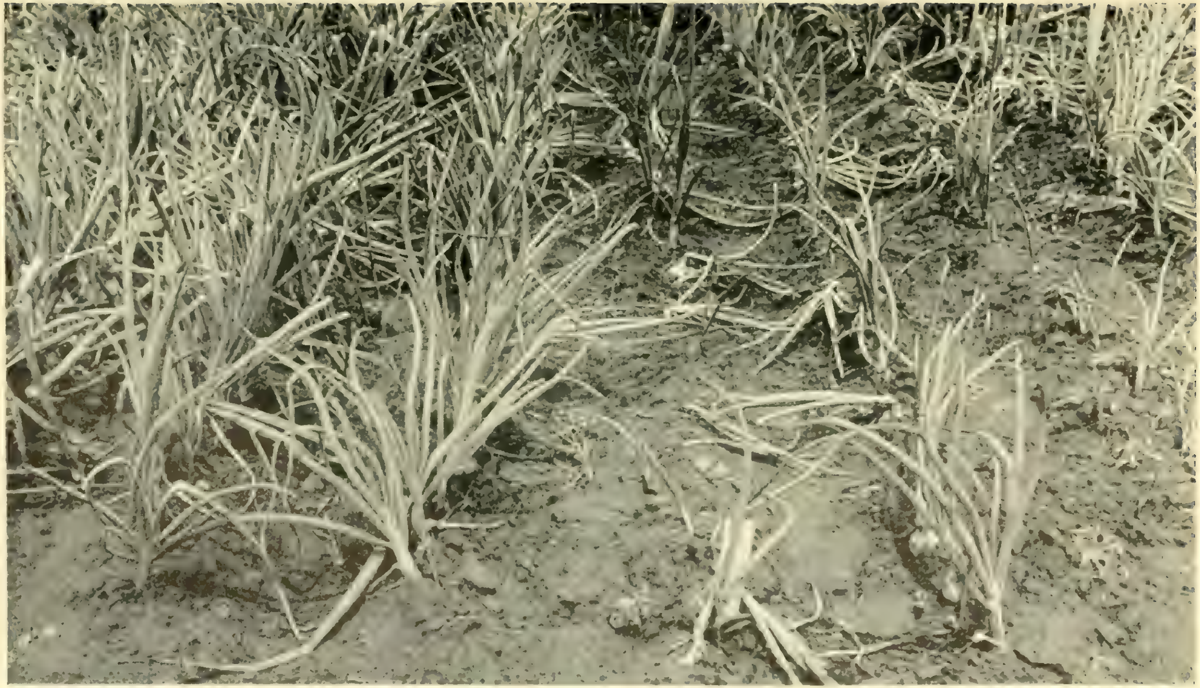
Growth of Domestic Rye Grass Cover Crop
seeded on onion land August 12 and photographed two months later



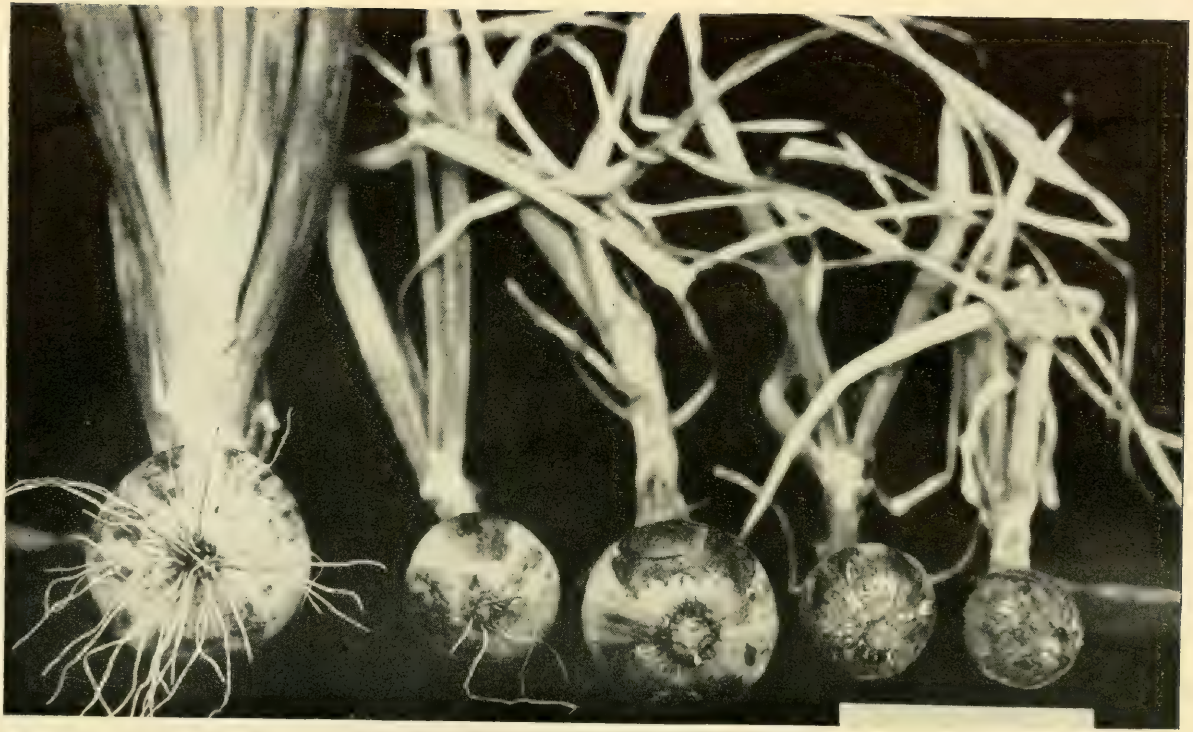
Uneven Fertilizer Distribution
shown by more vigorous growth of cover crops where fertilizer was concentrated in tractor rear wheel ruts. Arrows show path of wheels.



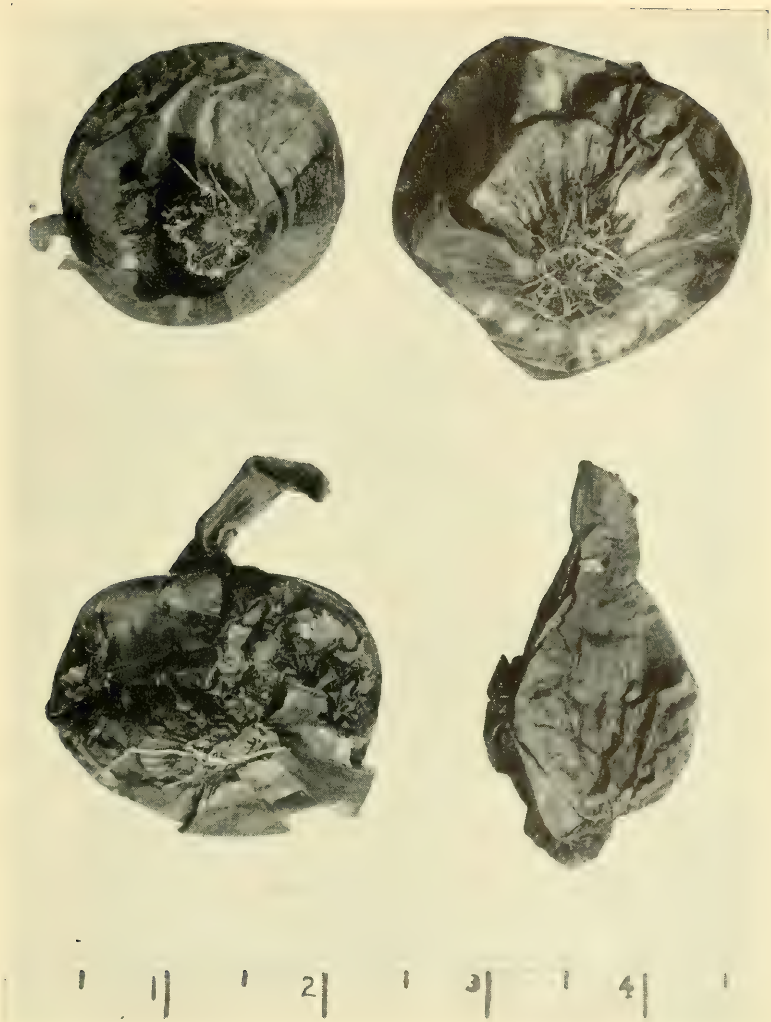
Fertilizer Injury on Set Onions.
Plant on right shows characteristic tip burn caused by a combination of heavy fertilization and insufficient moisture in the soil. Plant on left shows no injury.



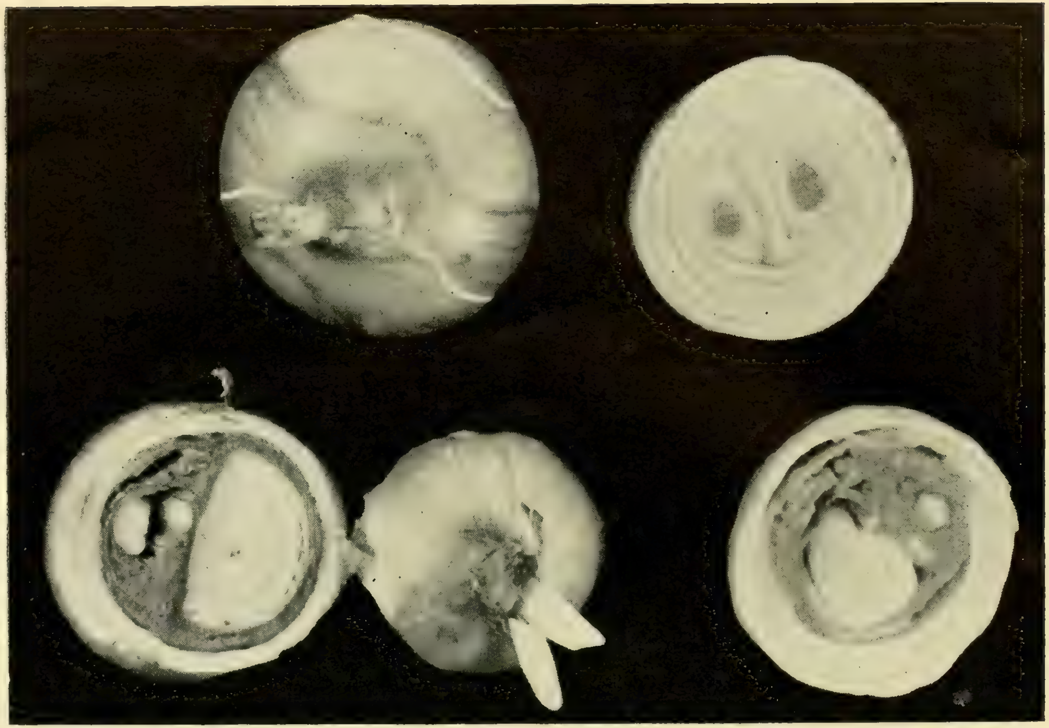
Excellent (left) and Poor (right) Crops of Onions
produced from two lots of sets which appeared
to be similar in quality at planting time.



Fusarium Rot on Growing Onions.
Normal bulb on left. Diseased onions on right show destruction of roots by the Fusarium and the resulting wilting and dying of the tops. The disease passes from the roots through the basal plate into the bulb.

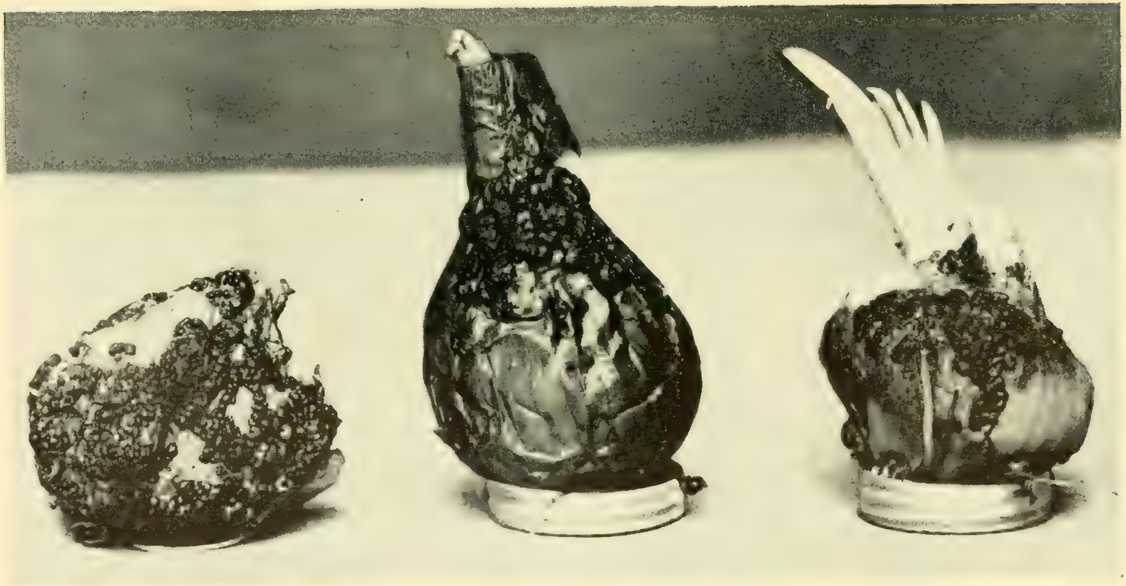


Fusarium Rot of Harvested Onions.
Many bulbs infected by this disease in the field appear sound when stored. In storage a white moldy growth develops on the bottom of the bulb, the tissues are destroyed, and the bulb becomes dry and shriveled.

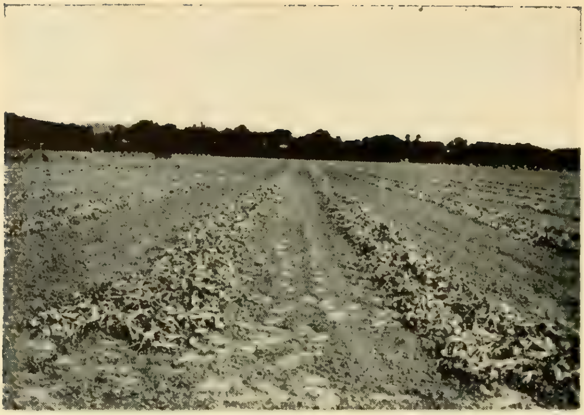


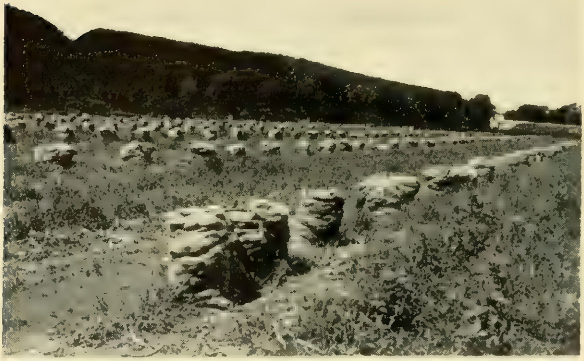
Bacterial Soft Rot.

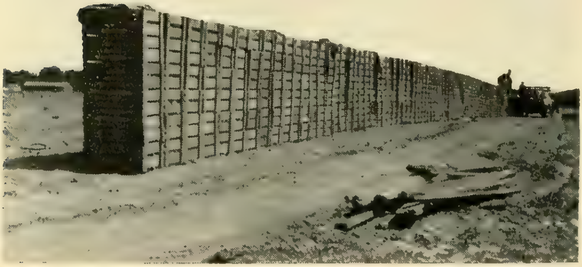
Top; Healthy onion entire and in cross section. Bottom; Sections of diseased bulbs showing how one or more inner scales may be invaded leaving the outer scales intact. Bulb in center with its top set to right shows how disease may induce premature sprouting. Soft rot in its early stages causes "leaky necks" and "slippery skins.'



Botrytis Neck Rot.
Black, cinder-like bodies, known as sclerotia, on the surface of onions show characteristic advanced stages of Botrytis neck rot. This storage rot was more serious when large quantities of seed onions were stored than it is now with set onions.







Harvesting and Curing.

Top: Onions Raked into Windrows to Dry and Cure after Pulling. Here they often lie on the ground for a week or more. Much infection may take place at this time, especially when the weather is wet and the soil moist.

Center: Bagged Onions Left Unprotected in the Field. Onions handled in this manner suffer serious losses from decay and deteriorate in quality because many sound bulbs become stained.

Bottom: Crated Onions Stacked in Tiers in the Field. Tar paper affords protection from the weather, and good circulation of air through the slatted crates promotes rapid drying and curing. Quality is maintained and losses from rot are kept to a minimum.

FACTORS AFFECTING LOSSES FROM DISEASE IN THE FIELD AND IN STORAGE

Weather

Seasonal weather conditions, more than any other single factor, determine the extent to which decay develops in the Connecticut Valley set onion crop. In general, high losses from decay follow wet seasons and low losses follow dry ones. The 1937 and 1938 growing seasons were abnormally wet, and losses from decay were high in most crops. The growing seasons of the two following years were abnormally dry, with the result that few instances of excessive loss from decay were reported.

The weather occurring the latter part of the growing season, more particularly during the time of harvesting operations, is most important. It is during this period that the average onion bulb is most susceptible to infection by disease organisms. Young, rapidly growing bulbs or mature bulbs that have been harvested and well cured are apparently much less likely to become infected. If the weather is wet during this critical period, the maturity of the crop may be delayed and harvesting and curing greatly prolonged. Many bulbs become infected by disease organisms so that subsequent losses from decay are high. If the weather is dry, the crop matures quickly and the harvested bulbs dry and cure rapidly. Few bulbs become infected and losses from decay are light.

While seasonal weather conditions have an important bearing on the yield and quality of the onion crop, nothing can be done directly to control them. However, there are other important factors affecting yields and quality of onions, which, if properly controlled, will offset to some extent the effects of unfavorable weather.

The Quality of Seed Sets

Locally Grown Versus Imported Sets.—The opinion is prevalent among local growers that onions grown from sets raised in the Connecticut Valley keep better in storage than onions grown from sets raised in other set-producing sections. To determine whether or not this is so, onion sets from different sources were grown in 1939 and again in 1940. The results for both years support the growers in their belief that locally produced sets give, on the average, a better keeping crop of onions. The following table summarizes some of the results obtained in 1939.

TABLE 6.—THE PERFORMANCE OF FIVE LOTS OF LOCALLY GROWN JAP SETS COMPARED WITH FIVE LOTS OF IMPORTED JAP SETS.

	Locally Grown Sets		Imported Sets	
	Yield Aug. 20 50 lb. Bags per A.	Percentage Loss by Oct. 20	Yield Aug. 20 50 lb. Bags per A.	Percentage Loss by Oct. 20
	844	19.0	663	13.3
	752	9.1	635	26.5
	696	5.2	579	27.7
	676	16.5	418	9.6
	567	10.6	410	33.3
Average	687	12.1	541	22.0

The percentage losses by October in 1940 were similar to those in 1939, but the average yields from the imported sets approached those grown from the local sets. The poor yields of imported sets in 1939 may be partially explained by the fact that an acute shortage of sets existed that year. Lots of very poor quality were shipped in and planted. Resulting yields were low and the keeping quality, in most instances, was poor. In 1940 when sets were plentiful and the quality was good, there were no significant differences between the yields of locally grown sets and of imported sets. However, the keeping quality of onions from imported sets was definitely poorer in 1940 as well as in 1939.

Factors Which May Affect Set Quality.—Unfortunately it is impossible, except in extreme cases, to determine from the external appearance of onion seed sets how the crop will yield or how it will keep in storage. Some lots were off color and had a considerable amount of fungus growth on the basal plate; yet the yields were good and shrinkage losses in storage were low. Other lots which appeared bright and healthy gave just the opposite results. In one experiment a number of sets from one lot were kept in a tightly closed container for two weeks just previous to planting. At planting time the sets were moldy and musty, yet they produced just as satisfactory a crop both as to yield and keeping quality as those sets kept under more favorable storage conditions. To account for the difference in performance between different lots of sets, it appears that studies should be made to include the production and storage of the sets themselves. The methods followed in each producing section should be compared. Soil differences between sections should be studied and the importance of the soil in each section as a source of inoculum should be determined. Do sets grown on land relatively free from bulb rot fungi produce a better keeping crop of onions than sets grown on old onion land?

The conditions under which onion sets are grown in the Connecticut Valley differ from those in other set-producing sections in the United States. Connecticut Valley sets are grown on light sandy soils with only moderate amounts of commercial fertilizers, while most imported sets are grown on soils which are naturally more fertile even without the addition of fertilizers and are also more moist. It may be that some of these factors play an important role in the keeping quality of the mature bulbs which are ultimately produced from sets grown under these different conditions.

Disease in Seed Sets.—Since the culture of set onions, from seed to marketable onions, requires two growing seasons, the chances of infection in the field and in storage are much greater than with seed onions. Infection may take place when the seed sets are grown, when they are stored in winter, when they are planted for the production of marketable onions, and again when the marketable onions are stored.

It was found from examinations of roots and basal plates of seed sets, in samples taken from 18 lots, that in some lots as many as 76 percent of the sets had spores of disease-producing organisms on them. In samples from other lots, cultures from the internal tissues of the basal plate revealed that 40 to 60 percent had fungus mycelia present, in most cases *Fusarium*. However, there was no correlation between the presence of spores on the surface or of mycelia in the tissues of the seed sets and the amount of rot which developed in storage in the onions grown from the sampled lots. In some cases, the onions from apparently clean sets rotted badly; in others, onions from apparently heavily infested and invaded sets developed little rot. Hence, the indication is that fungus spores on the surface of the seed sets or mycelia in the tissues is not an important factor in the rot of onions in storage.

Soil

Bacterial soft rot and Fusarium bottom rot, the two most important bulb diseases of set onions, are both caused by organisms commonly found in cultivated soils. It is only reasonable to expect that the soil itself might be an important source of inoculum while the bulbs are in contact with it, both during growth and after pulling, especially those soils on which onions have been grown continually for many years. Careful studies by Munn (2) in New York State, on the neck rot disease of onions, have shown that the soil is the source of the fungus causing this disease. Although such detailed studies have not yet been carried out on the organisms causing soft rot and bottom rot, convincing evidence from experiments conducted in the Connecticut Valley indicates that, under certain conditions, the soil is an important, if not the principal, source of inoculum for these diseases.

Some of the results obtained in 1941 are presented in Table 7.

Table 7.—Yields and Shrinkage Losses of Seven Lots of Set Onions Grown on Dry and on Moist Soils.

Lot and Type	Yield—50 lb. Bags per A.		Percentage Loss by Nov. 1	
	Dry Soil	Moist Soil	Dry Soil	Moist Soil
1 Jap	840	1050	15.6	39.6
2 Jap	840	1020	12.5	23.0
3 Jap	820	1010	12.5	33.4
10 Jap	870	960	42.0	56.3
11 Globe	880	1080	12.5	23.0
12 Globe	760	990	11.5	35.3
13 Globe	860	1060	8.4	33.5

Trials conducted in 1940 gave similar results. All plots were handled alike and in such a way, in the growing, harvesting and storing of the crop, as to insure the most favorable conditions for keeping in storage. In both years, seasonal weather conditions were good for growing onions. Onions grown on the drier, well-drained sections of the experimental area kept much better in storage than those grown where the soil was more moist. This was true for all lots of seed sets grown in both locations and indicates that the trouble began in the field long before the onions were put into storage.

These results show the importance of the relationship of soil moisture to bulb infection by disease organisms. They may show why in wet seasons, when the moisture content of most soils is high, the keeping quality of most onion crops is usually poor. They help explain why, in favorable years, some crops of onions keep poorly in storage even though the quality of the seed sets is excellent and storage facilities are good. Although onion soils as a whole are fairly uniform, minor differences in topography and soil texture exist, even within the same field, which result in some sections being much more moist than others. These moister sections would not necessarily be considered as poorly drained but onions from them would probably develop more rot in storage than those from the drier sections, even though weather conditions and other factors affecting keeping quality were favorable.

In these experiments yields were always greater from moist soils than from dry ones. Since the same number of sets was planted in each plot, the increased yields were the result of the bulbs growing to larger sizes. Larger bulb size may in itself be a factor contributing to disease. Large bulbs tend to be soft and succulent and they usually have a heavy, lush top growth. One might expect that they would be more subject to disease infection as they mature than would smaller bulbs. Valley growers have often observed that the large bulbs carry more disease than smaller ones.

It should be emphasized again that set quality is also important, for set lot 10 (Table 7) performed poorly on both dry and moist soils. This would indicate that sets of inferior quality produce bulbs with poor keeping qualities irrespective of soil conditions.

Crop Rotation

Another factor which may have an important bearing on loss by disease in storage is the building up of soil-borne diseases as a result of the continuous culture of onions for many years on the same land. There is some evidence to suggest that this occurs and that rotating onions with other crops would reduce diseases of onions in the field and in storage.

In Canada(3), by following a crop rotation of one year in corn, three years in alfalfa, and two years in onions, Fusarium rots were reduced from 40 percent to 1 percent and the yield was increased from 6 tons per acre before rotation to 15 tons the first year, and 16½ tons the second year, after rotation.

A small crop rotation experiment was started in the Connecticut Valley in 1939. On a section of field which had been in continuous onions for 40 years and from which onions usually rotted badly in storage, a plot was seeded down with mixed grass and clovers in the spring of 1939. The surrounding field was planted to onions by the owner. In the fall, after the onions had been harvested, a strip adjoining the hay sod was seeded to a cover crop of rye grass. In the late fall the rye grass and part of the hay sod, together with the adjoining field, were plowed. In the spring the whole area was planted to onions.

Yields at harvest time were similar for the experimental plots and the adjoining field but losses in storage differed considerably. Loss from rots in onions following onions was 17.3 percent; in onions following the rye grass cover crop, 22.4 percent; but in onions following one-year sod, only 13.5 percent. The results are indicative rather than conclusive because the experiment was not adequately replicated and could not be repeated.

Fertilizers

When large acreages of seed onions were grown in the Connecticut Valley, it was a common practice to topdress onions with a nitrogen fertilizer sometime during the growing season. Although this practice is much less common with set onions because of the shorter growing season, supplemental nitrogen is occasionally applied, particularly if the early part of the season is wet. The use of topdressed nitrogen fertilizers during the growing season frequently impairs the keeping quality of the crop. Losses from both rotting and sprouting may be heavy. Additional nitrogen often produces a larger, more succulent growth of both tops and bulbs and tends to delay maturity. Such conditions are favorable for the infection of many bulbs by storage rot organisms, and their subsequent development in storage may result in the destruction of many bulbs.

Time of Harvest

Growers have long felt that onions harvested during early maturity kept much better in storage than onions which had fully matured. Data from trials conducted in 1939 show that early harvesting does result in better keeping quality but at the expense of maximum yields.

Table 8.—Influence of Time of Harvest on Yield and Keeping Quality of Set Onions.

	Harvested when 50 percent of tops were "down"		Harvested 10 days later when all tops were "down"	
	Yield 50 lb. Bags per A.	Percentage Loss by Oct. 20	Yield 50 lb. Bags per A.	Percentage Loss by Oct. 20
Locally Grown Jap Sets	610	8.4	735	14.0
Imported Globe Sets	445	12.5	570	18.0
Imported Jap Sets	455	15.6	540	22.0

The early harvested onions had an average loss of 12.3 percent by October 20, while fully matured onions had an average loss of 18 percent. However, the fully matured onions yielded 20 percent more at harvest time, which in this instance more than offset greater losses in storage.

The results of this experiment supply further evidence that much of the disease infection takes place in the field late in the season. As the plants mature, the tops break over and the outer bulb skins loosen up. Greater opportunity is thereby afforded for the entrance of disease organisms, so that the longer the crop remains in the ground the greater will be the number of infected bulbs. The rank growth of weeds which usually takes place soon after the tops begin to go down is another contributing factor. Excess moisture from rains and heavy dews does not evaporate rapidly and conditions are favorable for disease infection.

Methods of Harvesting and Curing

The most common method of harvesting onions in the Connecticut Valley has been to pull the bulbs, rake them into windrows and clip off the tops. This may take from a few days to one or two weeks. Finally the clipped onions are put into used burlap bags and left standing in the field, where they may remain for several weeks more before they are screened and either marketed directly or placed in storage. It often happens that when the bags of onions are left in the field and on the ground the burlap bags rot out completely where they come in contact with the ground and it becomes necessary to turn them end for end.

All available evidence shows that once the necks of mature bulbs are fully cured and dry, they are not easily infected. The critical period begins with approaching maturity and continues until the necks have completely dried down. As long as the bulbs are in contact with the ground during this ripening and curing period, infection can take place readily. It is obvious, therefore, that weather conditions during harvesting and curing can have an important bearing on the keeping quality of onions in storage. If dry clear weather predominates during this period, the method followed in harvesting and curing makes very little difference. For example, in 1940, when the rainfall for August and September was only a little more than one third of normal, onions left on the ground for as long as two months did not differ in quality or amount of rot from onions removed to storage immediately after clipping.

When wet weather prevails at harvest time, the present methods of handling onions during harvesting and curing are conducive to excessive shrinkage and reduced quality. Even perfectly sound bulbs, when left in the field for several weeks, may become so stained that their marketability is adversely affected.

The 1941 season, while moderately dry, was wetter than 1940. Experiments carried on in 1941 effectively demonstrate the importance of removing bulbs from contact with the ground and giving them protection as soon as possible after pulling. Table 9 shows this clearly.

TABLE 9.—EFFECT OF HARVESTING METHODS ON KEEPING QUALITY—WEATHERING IN THE FIELD COMPARED WITH IMMEDIATE PROTECTION AFTER PULLING.

Method of Harvest	Locally Grown Sets Percentage Loss by Nov. 5	Imported Sets Percentage Loss by Nov. 5
Onions harvested, stored in bags immediately	9.5	20.5
Onions harvested, bags exposed 6 weeks in field before storage	15.0	27.2

In this experiment the bulbs which were given protection were put into 50-pound onion bags and loosely stacked in a well-ventilated storage building. This method is not practical for general use, since such storage facilities are not available to the average grower. However, another experiment, also carried out in 1941, showed that placing the onions in slatted crates stacked in well-ventilated protected tiers in the field was just as effective in keeping losses to a minimum as placing them in bags in storage.

Storage Conditions

Although no experimental work was carried on to show the direct effect of different storage conditions on the keeping quality of onions, frequent visits were made to different commercial storages in the Valley to observe conditions as they existed. In general, the conclusions drawn from these observations agree quite closely with much experimental work that has been carried on elsewhere. Low humidity and cool temperatures retard the growth of sprouts and check the rate of development and spread of rots, while high humidity and high temperatures have the reverse effect.

Cool, dry storage conditions are indispensable for the satisfactory storing of onions but will not prevent onions from rotting. To reduce the amount of rot in storage it is necessary to reduce the number of infections which take place in the field. Once a bulb becomes diseased little can be done to stop the development of the infection, although the growth of the invading organism is retarded by low humidity and cool temperatures in storage. M. T. Munn (2) states that "but very little secondary infection is believed to take place in storage, since the 'contacts' (those healthy bulbs lying against diseased bulbs) very seldom become diseased unless the storage house is very damp and the dry outer skins become soft and full of water. The dry outer scales are usually the last to rot and the disease does not seem to spread from onion to onion thru the dry skins."

Shortening the time required for harvesting and curing is one of the best and most practical methods of reducing losses in storage. This involves clipping immediately after pulling, removal from contact with the ground at once, and protection from the weather with adequate ventilation so as to complete the curing process rapidly.

SUMMARY

Onion production in the Connecticut Valley is now largely confined to the growing of set onions. Experimental studies conducted from 1939 to 1941 inclusive, on certain phases of the growing, harvesting, and storing of set onions have shown that:

1. Repeated working of the soil with heavy tractors following fertilization may bring about an uneven distribution of the fertilizer and result in some crop injury.
2. Domestic rye grass plowed under in the late fall is the most successful cover crop yet tried on onion land.
3. A characteristic dying back of onion leaf tips in mid-season can usually be attributed to fertilizer injury. It is caused by a combination of dry weather and heavy rates of fertilization.
4. In favorable growing seasons, Globe type varieties have produced excellent yields of high quality onions but their performance over a period of years has not been as consistent as that of the flat type Ebenezer variety.
5. Hand-planted sets, because of their uniform spacing and placing, will outyield machine-planted sets; but in most instances economies in production costs resulting from the use of machine planters will more than offset the reduction in yield.
6. Maximum yields of marketable onions are usually obtained if sets ranging from ½ to ¾ inch in size are spaced 2¼ to 2½ inches in rows 13 to 14 inches apart.
7. The successful control of weeds is essential. Tractor cultivation can be practiced during the early part of the growing season, but as the crop develops care must be exercised to avoid serious injury to the roots. Rows must be spaced at least 14 inches apart.
8. Seasonal weather conditions affect the keeping quality of onions more than any other single factor. Storage losses are usually high following wet seasons and low following dry ones.
9. The quality of seed sets is an important factor in the keeping quality of the mature bulbs, but the conditions which affect seed set quality have not as yet been determined.
10. Onions from locally produced seed sets have generally kept better in storage than onions from sets grown outside of the Connecticut Valley.
11. The soil appears to be the principal source of inoculum for onion bulb rot diseases, and soil moisture appears to be the most important factor in promoting their development and prevalence.
12. Early harvested onions, although yielding less, keep better in storage than late harvested onions. Onions for storage should be harvested before all of the tops are down.
13. In harvesting onions, it is important to pull, clip, cure, and get the bulbs under cover as soon as possible. They may be placed in slatted crates stacked in tiers in the field or they may be put into 50-pound onion bags and loosely packed in a well-ventilated barn or storage.
14. Onions in storage must be kept dry; and the colder they are kept without freezing the better.

LITERATURE CITED

1. Bokina, Carl J.: "The Present Status of the Onion Industry in the Connecticut Valley", Master's Thesis, Massachusetts State College, 1939.
2. Munn, M. T.: "Neck-Rot Disease of Onions", New York (Geneva) Agr. Exp. Sta. Bul. 437, 1917.
3. Woolliams, G. E.: "Progress Report of the Dominion Botanist for 1931-34", p. 77, 1934.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
3M-3-45-16025.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

AUG 13 1945

Bulletin No. 425 April 1945

Grass Silage

By J. G. Archibald and C. H. Parsons

The storing of grass and legume crops as silage has become an accepted practice. This bulletin, a revision of an earlier issue, reports the most recent findings on the subject.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

GRASS SILAGE[1]

By J. G. Archibald, Research Professor, and C. H. Parsons,
Assistant Professor, of Animal Husbandry

Introduction

During the past decade the making of silage out of grasses, legumes, and small grains, has become an accepted alternative method of storing these crops. Like many other developments in our agricultural practice, when first introduced and for a few years thereafter it became almost a fad. In their enthusiasm some people thought it would revolutionize our entire system of storing roughage, while others led astray by extravagant claims expected too much of it and as a result were disillusioned if not disappointed. Fortunately that phase of the situation is now pretty much a matter of history; farmers and professional agriculturists generally have come to recognize the practice as a supplement to, not a substitute for, ordinary hay making, to be relied on especially in unfavorable haying seasons and on those farms where the hay acreage is large, to aid in solving the problem of storage space and to help shorten the haying season.

Use of Preservatives

Since an earlier bulletin on the subject was published (April, 1939), much work has been done at this station and elsewhere on the problem of preservatives for grass silage.[2] The question is twofold; viz., are preservatives really necessary, and if so, what materials are satisfactory to use for the purpose?

As to the necessity for using preservatives the evidence is conflicting. Some investigators and operators report complete satisfaction when the crop is wilted and no preservative is added. Others have not been able to produce satisfactory silage unless a preservative has been added. The reasons for this situation are not far to seek. They lie in the facts that (a) under conditions of practice, e.g., unfavorable weather and/or labor problems, it is sometimes not possible to wilt the crop to a sufficient degree; (b) many operators are unfamiliar with what constitutes a proper degree of wilting; and (c) with some crops, especially the small grains, it is much easier to produce good quality silage without preservatives, than it is with some of the grasses. Also, because of limited experience many operators report that they have secured good quality silage when oftentimes the quality, if rated by someone competent to judge it, would be considered mediocre at best.

Where the wilting procedure is followed, the range of moisture permissible for success is not less than approximately 60 percent nor more than approximately 70 percent. Insufficient wilting without preservative results in an ill-smelling silage containing excessive amounts of butyric acid and ammonia; excessive wilting results in spoilage due to growth of molds because the crop is too dry to pack sufficiently to exclude all air.

---

[1] This bulletin is a revision of Massachusetts Agricultural Experiment Station Bulletin 362, which it supersedes.

[2] The term "grass silage" as used throughout this publication is a general designation meant to include, as indeed it does in general usage, silage made from the legumes and small grains as well as from the grasses.

Since grasses and legumes at the proper stage for ensiling contain more than 70 percent and sometimes as much as 80 percent of moisture, it follows that some wilting is almost always necessary when a preservative is not used. Some sort of equipment for determining the approximate amount of moisture in a wilted crop is therefore essential, especially for the novice. There is on the market at least one such device but its cost is high unless shared by several farmers. Less accurate but probably a sufficient guide is a homemade device recommended by the Bureau of Dairy Industry, United States Department of Agriculture. This can be made from materials available on most farms by anyone possessed of a little mechanical aptitude. Plans for it are given on the last page of this bulletin, also a table showing how to interpret results from its use.

Preservatives Investigated

Where for any reason wilting is not practicable, as for example in the operation of field choppers, some sort of preservative is essential to the production of good quality grass silage. The one exception is silage made from the small grains, especially if the grain has reached the dough stage. Numerous substances have been used as preservatives, and most of them have been investigated by this station. For the most part they fall into one of two categories: (1) those in which the acid needed to prevent spoilage is added directly, and (2) those which contain sugar or other readily fermentable carbohydrate, in which case the needed acid is a by-product of the silage fermentation.

Typical of the first class is phosphoric acid. Since wartime demands have pre-empted most of the production of phosphoric acid for more essential uses, not so much is heard about this acid as a silage preservative. It was given a three-year trial at this station in 1938-40. Although it was easy to apply and did a good job of preservation, the silage was not very palatable, being quite inferior in this respect to the silage produced with certain other preservatives.

Molasses has been the most frequently used of preservatives in the second class. Although there have been some failures with it, experience leads to the belief that they have been due to use of an insufficient amount. In general, when properly distributed in adequate amounts, molasses produces a sweet-smelling, palatable silage. Its disadvantages are that it is a bit messy, and oftentimes will not flow fast enough to keep pace with the chopping capacity of a cutter, thus necessitating dilution with water which means considerable extra labor. The minimum amount of molasses recommended is 60 pounds per ton of green crop; more recent experience has demonstrated that the 40 pound minimum recommended in the earlier bulletin is too low.

Under conditions prevalent since 1942 molasses has become relatively high priced and hard to obtain; the natural result has been a search for substitutes. Most success has been attained with some sort of ground grain; all of the cereal grains have been used. The action of such material apparently is two-fold. Besides furnishing an abundance of readily fermentable carbohydrate, the ground grain soaks up much of the excess moisture from the green crop, and the result is a moisture content in the whole mass of silage more nearly optimum for best results, not to mention reduction of objectionable seepage. For example, the addition of 150 pounds of ground grain with a moisture content of 10 percent to a ton of green crop containing 75 percent moisture will reduce the moisture content of the total mass to just about 70 percent.

Excellent silage was made at this station in 1943 by the addition of 150 pounds of ground wheat per ton of green crop, and in 1944 by addition of a similar amount of so-called "corn meal blend." This latter material, although consisting mostly of corn meal, contained some ground oats and ground barley. Silage made in this way has been exceptionally palatable to cows and has the further advantage of being relatively easy to make. The correct amount of grain for a load is weighed out and is slowly poured into the blower through one of the rows of air holes in the hood, as chopping proceeds. The operation is facilitated by bolting to the blower hood a homemade chute made from galvanized sheet metal and strap iron.

The apparent disadvantage of this method is the cost of the grain, but it should be borne in mind that most of the feed value of the grain is conserved, so that the actual cost for preservation is probably not any higher than for other common preservatives. One group of farmers when told about this method, expressed themselves in this way, "We have to buy the grain anyway; if there isn't much loss in the silo why not make it serve the double purpose of preservative and feed." Under present conditions regarding feed supply in the Northeast (February, 1945) it would be unwise to recommend this use for grain, but when grain is available in normal amounts the method is well worth a trial.

Other materials which we have given a trial as preservatives are lactic acid cultures, salt, a combination of these, and urea. As the name perhaps implies, lactic acid cultures are suspensions in suitable media of large numbers of certain types of bacteria, which ferment carbohydrate with the production of lactic acid. The particular species of organism used in our trials was *Bacillus bulgaricus*. The theory on which use of such cultures is based is that inoculation of silage with them will result more certainly in a typical lactic acid fermentation, which is the kind desired in silage, than if the mass is left uninoculated and nature is allowed to take its course.

Such cultures, used alone and in combination with salt, were investigated over a period of two years, with disappointing results. In many respects they were worse than no preservative at all for they encouraged the formation of butyric acid and other malodorous substances, and inhibited the development of lactic acid which they were supposed, in theory, to increase. It is felt that the inoculation theory breaks down for two reasons: (1) sufficient numbers of lactic acid-producing bacteria are present naturally, and (2) most grasses and legumes in the unwilted state do not contain sufficient fermentable carbohydrate for this type of bacteria to work on, regardless of whether they are present naturally or are introduced by inoculation. Furthermore, in many cases where success has been reported in the use of cultures, conditions were probably such that a fair to good product would have been obtained anyway, regardless of the inoculation.

Results with salt alone were equally poor. Aside from a favorable effect on palatability salt has little to recommend it as a silage preservative. Salt may keep damp hay from spoiling, but its effect in this respect is not operative in material as moist as silage. There is also the risk of too high a salt intake by animals fed silage to which salt has been added indiscriminately, as apparently was the case with one lot of silage examined in the course of this investigation. A sample from this lot contained seven times the maximum amount of salt recommended as adequate for milking cows. This was an exceptional case, but several other samples analyzed contained amounts of salt considerably above the recommended maximum.

Urea proved entirely unsuitable as an addition to silage. It was used not so much with the idea that it might have a preservative action as to increase the nitrogen content of the silage and hence its potential protein level for ruminants. Chemical examination of the silage showed that a considerable portion of the urea was converted into ammonia and lost in the leachings from the silo. The silage had a very objectionable odor and was unpalatable to cows.

To sum up briefly the present status of knowledge on the use of silage preservatives -they are not needed for corn, nor for the small grains when reasonably mature (dough stage), nor wherever it is feasible to practice wilting of grasses and legumes. Where for any reason wilting of grasses and legumes cannot be practiced, the preservatives which give assurance of a good quality silage are molasses or some kind of ground grain. It should perhaps be added that another alternative to wilting the grass, is to let it grow to such a stage of maturity that its moisture content is down to 70 percent or less. This alternative should be used only as a last resort because the nutritive value of the grass, especially the vitamin and mineral content, is lowered progressively as the crop approaches maturity; also such mature crops are more easily made into hay, a fact which lessens the motive for storing them as silage. On the other hand, such relatively mature material would be more palatable and probably more digestible as silage than as hay, provided it is not too mature to pack well.

Harvesting Methods

Where wilting is practiced, the crop must be left in the swath for from one or two hours to half a day or more, depending on weather conditions and the succulence of the crop. Under such conditions the best rig is the side-delivery rake followed by the green hay loader. When a green hay loader is not available, an ordinary hay loader can be used on this partly dried material provided caution is used not to roll up too large a windrow with the side-delivery.

Where wilting is not practiced, the mower may be equipped with a windrowing attachment for the cutter bar which eliminates the raking operation. The green hay loader is essential for this unwilted material—the standard hay loader is subject to too much breakage with heavy green crops to be practical. The same could be said of the earlier types of green hay loaders but many improvements have been made since these were first put out and more recent types are of more rugged construction and improved design. The raker bar cylinder type with metal deck seems now to be the accepted design.

The most recent development in green crop harvesting is the field chopper which combines in one tractor-powered outfit the three operations of cutting, chopping, and loading. These machines have reached the practical stage and are reported as giving satisfaction with all types of forage crops from corn to alfalfa. Such an outfit does away with much hand labor and the need of a chopper at the silo, only the blower-elevator being required. A field chopper cannot be operated to advantage on small fields, and obviously wilting cannot be practiced where one is used.

Control of Seepage

One problem that has arisen on many farms where grass silage is stored has been that of seepage control. Oftentimes succulent green crops are stored without wilting, and in some cases additional water is used, either for dilution of molasses or because it is erroneously considered necessary. Frequently this results in excessive drainage from the base and through the walls of the silo; the liquid collects in a low spot in the barnyard and becomes an unmitigated nuisance from the standpoint of odor and flies.

The problem can be controlled in two ways. The first is to safeguard against excessive seepage beforehand (1) by wilting very succulent crops, (2) by adding some moisture absorbent at chopping time—the incidental absorbent effect of ground grain used as a preservative has been noted earlier in this bulletin; some old hay or straw chopped in with the succulent crop is another expedient, (3) by refraining from adding water except when necessary for dilution of molasses—unlike corn which oftentimes gets considerably dried out before it is ensiled, grasses and legumes do not require additional water; better silage will result if they are not "wet down," and (4) wherever practicable to do so, by having the material that goes into the bottom half of the silo somewhat drier than that in the top half.

The other method is to provide drainage in the silo bottom for the excess liquid to get away underground. This can be done by having a gravel base which in porous soil will act as a dry well, or by having a tile drain which leads off the seepage to some larger drainage channel such as a ditch or small stream Under no circumstances should any attempt be made to retain the excess liquid in the silo; it is so dilute that the loss of nutrients is very small under most conditions of practice, and any saving of nutrients by attempting to make a silo leak-proof is more than offset by deterioration in quality in the lower levels of the mass of silage. The excess liquid makes the silage soggy, sour, and unpalatable.

In short, good ensiling practice will shut off seepage at the source if that is possible; if not, make provision to have it drain off freely so that it will not lower the quality of the silage or constitute a nuisance.

Composition of Grass Silage

A considerable amount of data has accumulated on this subject since our original bulletin was issued. Table 1 summarizes the composition of silage from various crops analyzed in the course of investigations over a period of nine years. It also indicates some of the changes in composition of the crop which are a result of the ensiling process.

In general the silages made from grasses, legumes, and small grains were higher than corn silage in all constituents determined except carbohydrates. The low carotene values for potato silage are what might be expected; potato tubers do not contain carotene; the small amount found comes from the relatively small amount of roughage mixed with the potatoes at chopping time.

The principal effects of the ensiling process on composition are to decrease the protein and carbohydrates somewhat, and to increase the fat and fiber. The losses are caused by some fermentation of the carbohydrate (which is inevitable in the nature of the process) together with some protein breakdown which accompanies the fermentation. The gains of fat and fiber are of course relative only; in the case of the fat the increase simply represents a transfer from the carbohydrate, because of the formation from it of certain organic acids such as lactic and acetic, which in conventional methods of analysis are determined as crude fat (ether extract).

The lack of agreement on carotene preservation between the two groups of data is believed to be due to sampling error in the lots of silage represented in the second group, although other investigators have noted at times that apparent carotene values may be higher in silage than in the crop from which it is made. In general some carotene loss is to be expected in the making of silage, although it is less than in any other process of curing and storing roughage, excepting artificial dehydration.

TABLE 1.—THE COMPOSITION OF GRASS SILAGE[1]

Kind of Crop	Number of Lots	Original Moisture	Protein	Fat	Fiber	Carbo-hydrates	Minerals	Carotene in Fresh Silage
		Percent	*Percentages in the fresh material*					*Units per lb.*
Mixed grasses	12	71.6	3.02	1.01	9.97	11.36	2.64	28,180
Mixed grasses and legumes	19	70.9	3.48	.94	9.80	11.26	2.47	27,770
Timothy	5	73.9	2.87	1.06	10.79	11.22	2.06	37,920
Legume	6	74.0	4.24	1.07	8.78	11.00	2.91	27,530
Small grain	6	72.8	2.60	.94	10.44	11.52	2.49	24,030
Oats – peas	3	67.3	2.92	.95	10.02	11.69	2.43	17,210
Potato – alfalfa	1	64.1	4.15	.48	6.70	14.96	1.70	600
Potato – oat hay	1	66.2	2.41	.35	6.26	17.33	1.65	670
Corn – for comparison	6	73.5	2.34	.77	8.43	14.87	1.59	15,480
Changes in Composition as a Result of Ensiling								
Mixed Grasses								
Before ensiling	3	75.3	3.29	.78	9.31	12.38	2.25	38,980
After ensiling	3	72.9	2.61	1.06	10.82	11.15	2.37	19,580
Mixed Grasses and Legumes								
Before ensiling	8	72.6	3.70	.69	8.88	12.31	2.42	20,460
After ensiling	8	70.3	3.41	1.05	9.93	11.23	2.39	24,710

[1] In order to have all values except original moisture comparable, they have been converted to a uniform basis of 72 percent moisture, which was the average moisture content of the 59 lots of silage reported in the first section of the table.

Potato Silage

During the past two seasons, as a result of the price support program of the federal government, surplus potatoes have been available for feeding to livestock. In 1944, 137 carloads of small potatoes were disposed of in this way in Massachusetts; many farmers fed them to livestock as such, either raw or cooked; others, following directions furnished by the War Food Administration through the college and county extension services, made them into ensilage by mixing them with a few hundred pounds of some kind of roughage and chopping in the usual manner.

Reports thus far indicate that for the most part a good grade of silage was obtained, although a few failures have been noted. The composition of two lots of such material has been noted in the preceding section of this bulletin. Quality of one of these was excellent, of the other only fair. More serious than any failure to obtain good silage has been the damage to cutter knives by stones, reported by some farmers. Where potatoes are grown on stony or gravelly land, stones frequently get mixed in with them because mechanical harvesters do not screen them out. Stones of a certain size, shape, and color so closely resemble a potato that they defy anything but the closest scrutiny, and no practical means of eliminating them is known that does not involve considerable extra labor.

It is our belief that surplus potatoes might much better be diverted to the manufacture of industrial alcohol, thus releasing corresponding amounts of corn and other grains for livestock feeding. The idea of making potato silage is not new; it has been practiced in Europe for many years, particularly in Germany. There they are ensiled almost entirely in stacks and trenches, a system that has not found favor in New England.

All in all, it would seem that, under our conditions, the best method of disposal of potatoes if and when they are fed to livestock, is to feed them out as such, raw for cattle, cooked for swine or poultry.

Summary

The making of grass silage has become an accepted alternative method of storing forage. It should be recognized as a supplement to, not a substitute for, ordinary hay making.

A good quality of grass silage can be made without a preservative by wilting the crop to the proper moisture content. When for any reason it is impracticable to wilt, some preservative is necessary for succulent grasses and legumes. Corn never needs a preservative, and the same is true for the small grains if they have reached a proper degree of maturity (dough stage of the grain).

Suitable preservatives are molasses or any kind of ground cereal grain. The minimum amount of molasses recommended is 60 pounds per ton of green crop. A suitable amount of ground grain is 150 pounds per ton, applied through the blower as chopping proceeds.

Urea, lactic acid cultures, salt, and a combination of culture and salt, proved unsatisfactory as silage preservatives.

Harvesting is best done with the special loading machinery now recommended for handling the heavy green crop. Where wilting is practiced, the side-delivery rake can be used; where wilting is not practiced, a windrowing attachment for the mower eliminates the raking operation. Field choppers are proving their merits in service; where they are used wilting is impractical.

Seepage should either be controlled at the source or if unavoidable should be allowed to drain off. Adequate drainage should be provided for it to obviate the nuisance of odor and flies. Seepage need never be a source of serious loss of nutrients.

Regardless of the crop from which it is made, grass silage is quite different in composition from corn silage, containing more protein, fat, fiber, and minerals and less carbohydrates.

Principal changes in composition as a result of the ensiling process are a decrease in protein and carbohydrates and a corresponding relative increase in crude fat and fiber.

The Homemade Moisture Tester

The following description of the materials needed and the procedure to follow in using the tester is taken from United States Department of Agriculture Leaflet 238.

1. A piece of 2-inch pipe, 12 inches long, open at both ends. Four rows of 3/16-inch holes should be drilled in the pipe, 10 holes to the row, and the rows should be equally distant apart. Starting ½ inch from one end of the pipe, drill the holes in each row ½ inch apart from center to center. Smooth off the burrs made by the drill on the inside of the pipe.
2. A round hardwood plunger 14 inches long beveled like a cold chisel on one end and flat on the other. It should fit the inside of the pipe snugly yet move freely.
3. A 2 x 4 lever 4½ feet long. Use the lever flatwise, with the beveled end under a beveled block nailed to the wall. Stand the testing pipe on a flat surface (wooden block or cement floor) near the wall, so the top of the plunger will fit in a small groove on the under side of the lever 1 foot from the edge of the block on the wall.
4. The material to be tested should be chopped with the silage cutter—not by hand. Set the cutter for ¼-inch lengths, if possible. Press the material firmly into the testing pipe 6 inches deep, but do not tamp or press hard enough to squeeze out juice.

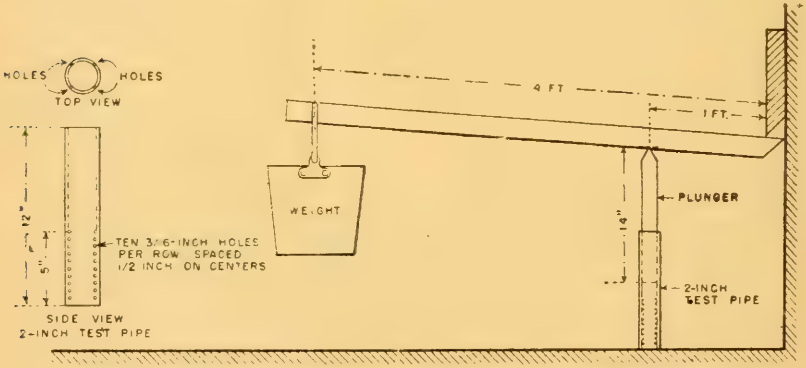


Figure 1 — Home-made tester for determining moisture content of grass silage.

In testing any kind of crop, either to find out whether it is too wet or too dry, use the weight specified in table 1. Hang the weight at the 4-foot mark on the lever and leave it *for* 1 *minute* for all tests.

If any juice whatever is expressed from any hole in the testing pipe by the weights shown on the "too wet" column (table 1), the moisture content of the crop material is approximately 68 percent or higher. If no juice is expressed by the weights in the "too dry" column, the moisture content is lower than approximately 58 percent.

In case a load has too much or too little moisture at the time of the test run it into the silo anyway, and then try to have subsequent loads nearer to the desired moisture content.

TABLE 1.—WEIGHTS TO USE IN TESTING DIFFERENT KINDS OF CROP MATERIAL

Kind of crop[1]	Length of cut	Too wet if juice is expressed by these weights[2]	Too dry if no juice is expressed by these weights[3]
	Inch	*Pounds*	*Pounds*
Legumes	¼	32	64
	½	41	.
Small grains	¼	50	82
	½	66	....
Grasses	¼	60	90
	½	79	

[1] For mixtures of these crops use intermediate weights depending on the proportion of the different crops.

[2] If these weights express juice, the moisture content is approximately 68 percent or higher.

[3] If these weights do not express juice, the moisture content is lower than approximately 58 percent.

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
3M-4-45-16163

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 426 APRIL 1945

Botulism and Home Canning

By William B. Esselen, Jr.

In order to answer some of the many questions which have been raised concerning botulism and home-canned foods, a summary of available information is presented.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

FOREWORD

In this bulletin, Professor Esselen is performing a needed service of much value to the many housewives in Massachusetts who, especially during these wartime days, are actively supplementing their own and the Country's food supply by canning fruits and vegetables for use in their homes.

The spoilage of canned foods, because of inadequate processing, is misfortune enough; but when there is added the danger of serious illness, and even death, from the eating of spoiled canned food, then misfortune becomes disaster.

That spoiled food can cause illness is not news to most people. We hear often of illness attributed to "ptomaine poisoning," which competent authorities now know is not caused by ptomaines but by active bacterial infections, or by poisons accumulated in foods by bacterial action. Botulism is the term applied to the illness caused by the most deadly of these bacterial poisons.

The basic facts about botulism are known to many people; but along the Atlantic seaboard, and particularly in New England, the attitude often taken, unfortunately, is that botulism is something to worry about only in the Rocky Mountain region and in the Pacific coast area, not in this region. That position is not entirely sound. It is readily granted that the danger is substantially greater in other regions of the country than here; but evidence concerning the distribution in the United States of the bacteria responsible for botulism indicates that no section of the country is entirely free from danger.

If botulism as a cause of death is compared with typhoid fever, tuberculosis, and many other bacterial diseases, the per-capita average is so small that it can be ignored as a menace to community health. Why, then, should we be concerned about it? Professor Esselen answers that question in his text when he states: "We are faced with a disease which, when it does strike, may kill an entire family." The State College is called upon to furnish directions and advice concerning home-canning methods, and its recommendations are received with confidence. For that reason it is vitally important that the advice given should be the best possible on the basis of existing knowledge; and there is no justification for risking the life of even one member of one family in the Commonwealth. In other words, we must think in terms of the health and safety of each individual rather than of the community as a whole.

James E. Fuller,
Research Professor of Bacteriology.

BOTULISM AND HOME CANNING

By William B. Esselen, Jr., Assistant Research Professor,
Department of Food Technology[1]

CONTENTS

Introduction . . . 3
What is Botulism . . . 4
Symptoms and diagnosis of Botulism . . . 4
Typical cases of Botulism from home-canned foods . . . 5
Outbreaks of Botulism from home-canned foods . . . 6
Where is *Clostridium botulinum* found . . . 11
Properties of the toxin produced by *Clostridium botulinum* . . . 15
What factors influence the growth of *Clostridium botulinum* . . . 17
Heat resistance of *Clostridium botulinum* . . . 21
Are home canning process times as recommended at present adequate . . . 21
Attitude of U.S.D.A. and food technologists toward home canning and botulism . . . 24
Summary . . . 26
Literature cited . . . 27

INTRODUCTION

The tremendous increase in home canning during the past two years has served to emphasize more than ever the question of botulism in home-canned foods. The importance of using a pressure canner for processing non-acid foods has been stressed by the United States Department of Agriculture and food technologists. It has been repeatedly pointed out that boiling water bath processing is not safe and that it therefore presents a serious hazard from the public health standpoint. Yet, on the other hand, it is well known that every year millions of jars of non-acid foods are apparently successfully canned at home and processed in a boiling water bath, particularly in certain sections of the country. We have been, and are, faced with a situation in which on the one hand the technologist states that boiling water bath canning is dangerous and should not be tolerated and on the other hand many millions of jars of non-acid foods are home canned in a boiling water bath every year according to directions supplied by many states, home canning equipment suppliers, public utilities and other agencies. This situation has been further complicated by the fact that people have been urged by the government to raise Victory Gardens and can as much food as possible but to use *only* a pressure canner for processing non-acid foods. Such a program has been confronted with the fact that many thousands of families do not own pressure canners and have been unable to obtain them. It is not surprising that many people have raised such questions as: — (1) "Why should I use a pressure canner now when we have been canning successfully for years with a boiling water bath?" (2) "I live in the eastern part of the country where they do not have botulism. Why should I use a pressure canner?" (3) "Botulism is but rarely encountered. Why should I be concerned about it?" (4) "Can anything be done to the non-acid foods canned at home in a boiling water bath to make

---

[1] Acknowledgment is due the Hazel-Atlas Glass Company, Wheeling, W. Va., for their interest and assistance in the preparation of this bulletin.

them safe so far as botulism is concerned?" (5) "How can whether or not my home-canned foods contain botulinus toxin?" (6) "Does te of a pressure canner automatically ensure safety from botulism?"

In order to answer some of these questions concerning botu and home-canned foods, a survey of the literature and available information been made and summarized in the following discussion. This subject should b particular interest to those persons or agencies who assume the responsibility roviding home-canning directions for the general public. An outbreak of botu. caused by a food carefully canned according to directions furnished to the p. c by a private concern or any other agency has grave implications.

WHAT IS BOTULISM?

Botulism has been defined as an acute toxemia caused by the ingestio f a potent toxin produced by an anaerobic spore-forming bacterium, *Clostr m botulinum*, widely distributed in nature. Unlike many types of food poiso g bacteria, the organism responsible for botulism produces its toxin in the f d during the process of food spoilage. When the food is eaten it is the toxin a not the bacteria that causes the poisoning. This organism produces spores whi are much more resistant to heat than other kinds of food poisoning bacteria ar it is difficult to destroy them in canning unless the foods are processed in pressure canner at a high temperature. The botulinus bacillus differs from man kinds of bacteria in that when it grows in food it may not produce any obvious signs of spoilage. Thus, jars of canned foods containing its toxin do not necessarily show evidence of spoilage which would warn the housewife that the food was unfit to eat. The term Botulism (Latin, *Botulus*, a sausage) was coined to apply to a particular type of food poisoning caused by eating spoiled sausages. According to Tanner (1933) it is no longer used with the restricted meaning, but is now applied to a group of symptoms irrespective of the food source of the poison which causes them. The spectacular symptoms, the suddenness with which they appear, and the high death rate combine to give botulism a place quite out of proportion to its frequency as a cause of death.

In the United States most outbreaks of botulism have been caused by canned vegetables, while in Europe many of the outbreaks, as indicated by the origin of the name, have been caused by preserved meats and sausage.

SYMPTOMS AND DIAGNOSIS OF BOTULISM

According to Damon (1928) a great variety of symptoms are observed in cases of botulism, but in general, the cases fall into two quite distinct groups, i.e., those in which there is an initial acute gastro-intestinal disturbance followed by symptoms of the poisoning and those in which the typical symptoms of botulism are manifest at once. The nervous symptoms are brought about as a result of absorption of the toxin in the food through the mucosa of the upper intestine.

In the cases observed in the United States, Geiger, Dickson and Meyer (1922) reported that the earliest recorded onset of the disease was two hours, while the most delayed was eight days, after ingestion of the toxic food.

In cases in which there is an initial gastro-intestinal disturbance there is usually a feeling of lassitude and fatigue, frequently accompanied by dizziness or headache and a burning sensation with some distress in the region of the stomach.

At the same time there may be nausea and vomiting with or without diarrhea. These symptoms seldom persist longer than 48 hours.

The disturbances of vision which soon follow, as evidenced by a dimness of vision, are often the first indication of the serious nature of the illness. Early in the illness the third cranial nerve is usually involved accompanied by a loss of reflex to light stimulation, and other disturbances of vision. The pupils are often irregular in contour and unequal, and complete loss of accommodation soon follows.

Swallowing and talking becomes difficult at the same time or soon after the onset of visual disturbance. The tongue may become somewhat enlarged and sluggish in its movement. One of the salient features of botulism is the extreme muscular weakness exhibited by the patient. Mentality is usually unimpaired during the disease. In uncomplicated cases the temperature remains subnormal during the entire illness.

As the disease progresses the action of the heart muscle becomes impaired and the pulse rate may become very rapid. The combination of rapid pulse and subnormal temperature is one of the striking features of botulism. As the respiratory muscles become fatigued there may be partial or complete asphyxia, and death is usually due to cardiac or respiratory failure.

When recovery does take place, it is an extremely slow and tedious process. When convalescence is complete there seems to be no permanent disability.

Botulism is characterized by a high mortality rate. Information based on outbreaks in the United States, Canada, and England has established a mortality rate of between 60 and 70 percent.

TYPICAL CASES OF BOTULISM FROM HOME-CANNED FOODS

In order to demonstrate the characteristics of botulism outbreaks, the following cases may be cited:

1. At Los Angeles, California, in 1920, a woman tasted of string beans from a can which appeared spoiled. She developed botulism and died the sixth day. Fowl botulism was caused among chickens which ate the remnants of the beans (Geiger, Dickson, and Meyer, 1922).

2. Home-canned string beans caused illness in three persons, two of whom died, at Rocky Ford, Colorado, in 1927. The beans had been put up according to procedure advised by a home canning jar supply company based upon a government bulletin. The beans had a foul odor during cooking (Tanner, 1933).

3. Five persons at Pueblo, Colorado, in 1921, developed symptoms of botulism after eating home-canned beets; three of them died. As far as could be determined, the beets possessed no undesirable characteristics (Tanner, 1933).

4. Three persons died from eating home-canned asparagus at Seattle, Washington, in November, 1917. The asparagus had been canned according to directions for the "cold pack" process and was processed for three hours in boiling water. Remnants of a salad partaken of by those who were ill was fed to chickens. They died of limber-neck, and a bacteriological examination of the crops and gizzards of ten chickens yielded a virulent strain of *Cl. botulinum*, Type A (Damon, 1928).

5. On Christmas day, 1928, a family from Fredonia, New York, and two from Westfield, New York, assembled in Westfield for a Christmas dinner. Twenty-five people were present, about half of the number being children. The dinner consisted of fresh killed chicken, macaroni and cheese, potatoes, bread, and home-canned green and yellow beans.

Six severe cases of typical botulism developed; the first showed symptoms in 24 hours, and the remainder within 72 hours. Of this number one died on the 27th, two on the 28th, and one on the 29th. A later report of a fifth death was received. The first four of these persons ate heartily of the beans, and it is probable the fifth did, also. The sixth, a child of nine years, said she did not, but she had severe typical symptoms.

Of the remaining persons at dinner, five tasted or, at most, ate only a few beans, and showed some symptoms; two others tasted of the beans but did not become ill; while nine persons who did not partake of this article of food remained well. One child was uncertain as to whether she had eaten of the beans or not, but showed no symptoms; while another, who had tasted of the beans, showed signs of "grippe." *Cl. botulinum*, Type B, was obtained from the empty jar which had contained the beans (Geiger, Dickson, and Meyer, 1922).

6. At Santa Cruz, California, in 1943, a woman died as a result of tasting the contents of a jar of home-canned beet greens containing botulinum toxin. The beet greens had not been processed in a pressure canner. When they were opened, it was noticed that they were not good and they were thrown out. Before throwing them out, the woman tasted them and decided definitely that they were not good and spat out what she had put into her mouth. This occurred on Friday and on Tuesday she died. Type A *Cl. botulinum* toxin was isolated from the canned beet greens (California Extension Service, 1943a).

7. In New Rochelle, New York, three cases of botulism, two of them fatal' occurred in a family as a result of eating a home-canned eggplant preparation· "The home-canned food mixture consisted of eggplant chiefly, green and red peppers, vegetable oils, tomato, dash of garlic, pepper and salt. This food mixture had been canned in August, 1943, by a member of the household who explained that the eggplant was washed, cut in slices and boiled for five to ten minutes in water with the tomato and garlic. The peppers were washed, cut in slices and fried in an oil product containing choice cottonseed and corn oils and extra fine olive oil. After the cooking process of the peppers and the eggplant had been completed, a portion of each was placed in nine hot sterile glass jars and sealed. The food was not processed in a water bath after it had been sealed. The food had not been heated before serving." A laboratory diagnosis showed that Type B botulinum toxin was present in the product (Hicks, 1944).

From a study of available information regarding botulism outbreaks from home-canned foods, it is obvious that almost without exception they have been caused by carelessness and the use of faulty canning techniques. The use of water bath processing or the open kettle canning method for low-acid foods with their resultant understerilization has been responsible for many outbreaks. It is likely that most of these outbreaks would not have occurred had the food been cooked sufficiently to destroy the toxin after removal from the can. A good illustration of this is shown in the outbreaks which occurred when a housewife tasted of the product before cooking it and then cooked it prior to serving on the table. In some such cases the housewife died while the rest of the family who partook of the cooked product were not stricken. Some cases of botulism from home-canned foods processed in a pressure canner have been reported. In such instances the underprocessing of the product probably resulted because the pressure canner was not in good condition or not correctly operated or improper process times were employed.

OUTBREAKS OF BOTULISM FROM HOME-CANNED FOODS

Unfortunately it is impossible to obtain a true picture of the number of outbreaks of botulism caused by home-canned foods. It is not a common and widespread type of poisoning and because of the infrequency of outbreaks it is not readily recognized by many physicians. It has been suggested that many cases have not been recognized as such and hence have not been reported. The fact that botulism is not a reportable disease in many states is another factor contributing to a scarcity of information on the subject.

About 1920, as a result of several serious outbreaks of botulism from commercially canned foods, commercial canners realized the importance of botulism as it affected their industry and spent hundreds of thousands of dollars to learn proper methods of processing. According to Tanner (1934) the result is that commercially canned foods in the United States have not caused an outbreak of botulism since 1925. On the other hand, home-canned foods cause numerous outbreaks each year.

In order to obtain a detailed picture of the outbreaks of botulism from home-canned foods in the United States a survey of available information was made. Data obtained from Geiger, Dickson and Meyer (1922), Tanner (1933), Meyer (1943), the National Canner's Association, the Journal of the American Medical Association, Public Health Reports, and other sources have been summarized in Table 1. One hundred and seventy-five outbreaks of botulism from home-canned foods which occurred from 1910 to 1944 are presented according to the date, geographical location, number of cases and fatalities, and the product involved. A few instances where poultry died from eating spoiled home-canned foods are included although the literature contains many more such cases. These 175 outbreaks resulted in 553 cases with 385 fatalities—a case fatality rate of approximately 70 percent. Although most such outbreaks have occurred in the Pacific Coast and Rocky Mountain states there have been a number of cases in the East. Few or no outbreaks have been reported from the areas comprising the Mississippi Valley, the Southern and Southeastern States, and the six New England States. It is interesting to speculate as to the reasons why botulism has not been reported in these latter geographical regions, for available technical information would indicate that the spores of the botulinus organism may be found in all parts of the country. The following factors have been suggested as possibly having a bearing on this situation:

1. In the New England States cool storage conditions tend to retard the growth of bacteria in home-canned foods.
2. In the South the long cooking periods frequently employed in the preparation of foods for the table would be sufficient to destroy botulinus toxin if it were present.
3. In many cases foods which were not completely sterilized would contain characteristic spoilage bacteria which would grow more rapidly and either inhibit the growth of *Cl. botulinum* or produce such obvious signs of spoilage in the jar that the contents would not be eaten. This condition might be more prevalent in the South where warm storage conditions would favor the growth of spoilage bacteria if they were present.
4. Botulism is not a reportable disease in many states and is not readily identified and recognized by many persons unless they have had occasion to become familiar with its characteristics and symptoms.
5. In many of the states with a well-organized home-canning program, great stress is placed on cleanliness and "two hours from garden to jar." Such practices would tend to keep the bacterial load of the product down to a minimum, eliminate the presence of decayed vegetables, and in general improve the effectiveness of a given canning procedure.

TABLE 1.—OUTBREAKS OF BOTULISM FROM HOME-CANNED FOODS IN THE UNITED STATES 1910-1944.

No.	Date	Location	Cases	Deaths	Food Responsible
1	1910	Sawtelle, Calif.	12	11	Pears
2	1910	North Yakima, Wash.	6	3	Asparagus
3	1912	Amador County, Calif.	6	5	String beans
4	1914	Stanford University, Calif.	12	1	String beans
5	1915	Ontario, Oreg.	1	1	String beans
6	1915	Fall Brook, Calif.	5	5	Apricots
7	1915	Hillsboro, Oreg.	1	1	Corn
8	1915	Sacramento, Calif.	1	1	Asparagus
9	1916	Yakima, Wash.	1	1	Corn
10	1916	San Pasquale, Calif.	1	0	String beans
11	1916	San Jose, Calif.	1	1	String beans
12	1917	New York State	7	5	Corn
13	1917	Yakima, Wash.	1	1	Corn
14	1917	Amador City, Calif.	6	5	String beans
15	1917	Corning, Calif.	1	0	Corn
16	1917	Seattle, Wash.	3	3	Asparagus
17	1917	Escondido, Calif.	8	4	String beans
18	1918	Yakima, Wash.	1	1	Corn
19	1918	Madera, Calif.	9	6	Apricots
20	1918	Fresno, Calif.	1	1	String beans
21	1918	Oakdale, Calif.	1	1	String beans
22	1918	Klamath Falls, Oreg.	1	1	String beans
23	1918	San Bernardino, Calif.	2	2	Apricots
24	1918	Colton, Calif.	1	0	Pears
25	1918	Newark, N. J.	3	2	Spinach
26	1918	Boise, Idaho	5	4	Asparagus
27	1919	Los Angeles, Calif.	1	1	String beans
28	1919	McKenna, Wash.	3	3	Spinach
29	1919	Decatur, Ind.	7	4	String beans
30	1919	San Rafael, Calif.	4	4	String beans
31	1919	Fresno, Calif.	1	1	String beans
32	1920	Pittsburgh, Pa.	4	3	Corn
33	1920	Florence, Ariz.	12	5	Beets
34	1920	Los Angeles, Calif.	1	1	String beans
35	1920	Los Angeles, Calif.	4	1	String beans
36	1921	Toppenish, Wash.	2	2	Spinach
37	1921	Grants Pass, Oreg.	1	1	String beans
38	1921	Okanogon County, Wash.	2	1	Beets
39	1921	Seattle, Wash.	1	1	String beans
40	1921	Yakima, Wash.	1	1	Corn
41	1921	Walla Walla, Wash.	1	1	Asparagus
42	1921	Walla Walla, Wash.	2	1	Spinach
43	1921	Yakima, Wash.	1	1	Corn
44	1921	Pueblo, Colo.	5	3	Beets
45	1922	Cambridge, Idaho	8	6	Beet and turnip greens
46	1922	Okanogon County, Wash.	3	3	String beans
47	1924	Sterling, Colo.	7	5	String beans
48	1924	Albany, Oreg.	12	12	String beans
49	1925	Buffalo, N. Y.	1	1	String beans
50	1926	Roberts, Oreg.	3	1	Trout or salmon
51	1926	New York State	1	1	String beans
52	1926	Powell, Wyo.	2	1	String beans
53	1926	Lockeford, Calif.	1	1	Asparagus
54	1927	Rocky Ford, Colo.	3	2	String beans
55	1927	Ono, Calif.	1	1	Corn
56	1927	Los Banos, Calif.	2	2	Pears
57	1927	San Francisco, Calif.	1	1	String beans
58	1927	Near Pleona, Mont.	4	4	Corn
59	1927	Los Banos, Calif.	2	2	Bartlett pears
60	1928	Boulder, Colo.	1	1	Corn
61	1928	Westfield, N. Y.	10	5	String beans
62	1929	The Dalles, Oreg.	4	1	Beets
63	1929	Yakima, Wash.	2	–	String beans
64	1929	Green Bay, Wis.	2	2	Celery
65	1929	Hudson, Wyo.	6	4	String beans

TABLE 1.—OUTBREAKS OF BOTULISM FROM HOME-CANNED FOODS IN THE UNITED STATES, 1910-1944—Continued.

No.	Date	Location	Cases	Deaths	Food Responsible
66	1929	Pueblo, Colo.	1	1	String beans
67	1929	Calcite, Colo.	4	2	Potatoes
68	1929	Rocky Ford, Colo.	3	2	String beans
69	1930	Golva, N. Dak.	?	4	?
70	1930	Trinidad, Colo.	3	3	Chile con carne
71	1930	Sidney, Nebr.	4	2	Asparagus
72	1930	Sentinel Butte, N. Dak.	4	2	String beans
73	1930	Torrance, Calif.	5	3	Tuna
74	1930	Peetz, Colo.	4	2	Asparagus
75	1931	Pueblo, Colo.	42 chickens		Corn
76	1931	Scottsbluff, Nebr.	2	2	Spinach
77	1931	Purcell, Colo.	4	2	String beans
78	1931	Amarillo, Tex.	2	2	Spinach
79	1931	Bishop, Calif.	–	1	String beans
80	1931	Saugerties, N. Y.	5	2	Greens
81	1931	Grafton, N. Dak.	16	13	Salad (peas, beans, carrots)
82	1931	Newport, Oreg.	2	2	Smoked salmon
83	1932	Bloomfield, N. Mex.	4	2	Chili peppers
84	1932	Pueblo, Colo.	2	2	Peppers
85	1932	Bordeaux, Wash.	1	1	Corn
86	1932	Verdel, Nebr.	3	3	Corn
87	1932	Borger, Tex.	2	2	Beet tops
88	1932	Jordan, Mont.	4	2	Pork
89	1932	Glenwood Springs, Colo.	1	1	Cauliflower
90	1932	Maryville, Tenn.	7	6	Vegetable soup mixture
91	1932	Biola, Fresno County, Calif.	1	1	Corn
92	1932	Philipsburg, Pa.	2	2	String beans
93	1932	Modale, Iowa	24 chickens	23	Corn
94	1932	Sams Valley, Oreg.	Horses and chickens		Carrots
95	1932	Cleveland, Ohio	–	–	String beans
96	1933	Hamilton, Mont.	1	1	String beans
97	1933	Coeur d'Alene, Idaho	2	2	String beans
98	1933	Miles City, Mont.	3	2	String beans
99	1933	Corma, Calif.	1	1	Beets
100	1933	Morro Bay, Calif.	2	2	Pickled beets
101	1933	Dayton, Wash.	3	3	Beets
102	1933	Lakeside, Ohio	3	2	Beets (?)
103	1933	Alamosa, Colo.	84 chickens and turkeys dead		Corn
104	1933	Missoula, Mont.	3	3	Beet greens
105	1933	Joseph, Oreg.	83 chickens dead		Spinach
106	1933	Spearfish, S. Dak.	1	1	String beans
107	1933	San Luis, Calif.	2	2	Green peppers
108	1934	San Francisco. Calif.	1	1	Mushrooms
109	1934	New Canaan, Conn.	?	1	String beans (?)
110	1934	Halfway, Oreg.	1	0	String beans
111	1934	Springer, N. Mex.	4	4	Corn and chili peppers
112	1934	Missoula, Mont.	2	2	Beet greens
113	1934	Baker, Oreg.	2	2	Spinach
114	1934	Yakima, Wash.	25	22	String beans
115	1934	San Jose, Calif.	5	5	Soy beans
116	1934	Walla Walla, Wash.	1	0	Asparagus
117	1935	Trinidad, Colo.	4	3	Beets
118	1935	Yakima, Wash.	4	2	String beans
119	1935	Sand Creek, Okla.	4	1	String beans
120	1935	Bernardsville, N. J.	5	3	Peppers
121	1935	Los Angeles, Calif.	2	1	Chili and beans
122	1935	Florence, Colo.	4	2	String beans
123	1935	Sidney, Mont.	4	2	Spinach
124	1935	Springer, N. Mex.	5	4	Peppers
125	1935	The Dalles, Oreg.	4	1	Salmon
126	1935	Scottsbluff, Nebr.	8	4	Corn
127	1935	Montebello, Calif.	1	1	String beans
128	1935	Miles City, Mont.	2	2	Spinach
129	1935	Wenatchee, Wash.	1	1	String beans
130	1935	Prairie City, Oreg.	1	1	Pears

Table 1.—Outbreaks of Botulism From Home-Canned Foods in the United States 1910-1944—Continued.

No.	Date	Location	Cases	Deaths	Food Responsible
131	1935	Cambridge, Idaho	1	1	Corn
132	1936	Argada, Colo.	1	1	Spinach (?)
133	1936	Lookout, Ky.	5	4	Corn
134	1936	Java, S. Dak.	3	2	Pears
135	1936	Watauga, S. Dak.	4	4	String beans
136	1936	Sundance, Wyo.	3	1	Beets
137	1936	Cokeville, Wyo.	4	2	Mushrooms
138	1936	Humbolt County, Calif.	1	1	String beans
139	1936	Los Angeles, Calif.	1	1	Corn
140	1937	Glendale, Calif.	2	1	Tuna
141	1937	Trinidad, Colo.	3	3	String beans
142	1937	St. Paul, Minn.	4	4	String beans
143	1937	Los Angeles, Calif.	1	1	Corn
144	1937	Circle, Mont.	13 chickens		Corn
145	1937	Columbus, Ohio	4	2	String beans
146	1937	Alliance, Nebr.	1 dog	1	Corn
147	1937	Tucumcari, N. Mex.	12	9	Chili
148	1937	Fresno, Calif.	2	2	String beans
149	1938	Los Angeles, Calif.	1	1	Corn
150	1938	Ellensburg, Wash.	1	1	Corn
151	1938	Wenatchee, Wash.	5	2	Beet greens
152	1938	Carlsbad, N. Mex.	2	2	Chili
153	1938	Long Beach, Calif.	2	2	Vegetables
154	1938	Lewiston, Utah	1	1	Pears
155	1938	Long Beach, Calif.	4	1	Tuna
156	1938	Everett, Idaho	1	1	Corn
157	1939	Medford, Oreg.	2	2	String beans
158	1939	Franklin, N. Y.	3	1	Spinach
159	1939	Sheldon, N. Y.	3	0	Cooked cheese
160	1939	Westmoreland, Tenn.	2	1	Okra (and beans)
161	1939	Seattle, Wash.	16	5	Carrots and peas
162	1939	Selma, Calif.	5	2	Unknown
163	1939	Sacramento, Calif.	1	0	Figs
164	1939	Hanford, Calif.	1	1	Black-eyed beans
165	1939	Monrovia, Calif.	1	0	Beet greens
166	1940	Buckhannon, W. Va.	3	2	Pickled tongue
167	1940	Brownsville, Tenn.	2	2	Tomatoes
168	1940	McCook, Nebr.	1	1	Corn
169	1940	Lefor, N. Dak.	4	2	Pumpkin
170	1941	Minatare, Nebr.	3	2	Tomatoes (?)
171	1941	Bismarck, N. Dak.	2	1	Corn (?)
172	1943	California	1	1	Beet greens
173	1943	New Rochelle, N. Y.	3	2	Eggplant and vegetable mixture
174	1944	New Rochelle, N. Y.	2	2	String beans
175	1944	Brooklyn, N. Y.	1	0	String beans
			553	385	

From Table 2 it may be seen that string beans and corn, followed by spinach and other greens, asparagus, and beets are the foods which have been largely responsible for botulism outbreaks from home-canned products. It is fairly obvious why these products have been involved. String beans are easy to grow and more of them are canned than of any other non-acid vegetable. The same trend holds true for the other products mentioned. String beans also are not a good medium for the growth of many bacteria and even if organisms do grow, their presence is not readily detected in many cases. Corn and greens are among the most difficult products to sterilize, because their consistency retards the rate of heat penetration into the jar during processing.

Table 2.—Food Involved in Outbreaks of Botulism From Home-Canned Foods.

Food	Number of Outbreaks	Food	Number of Outbreaks
String beans	57	Celery	1
Corn	30	Chili and beans	1
Spinach	12	Chili peppers	1
Beets	10	Corn and Chili peppers	1
Asparagus	9	Eggplant and vegetable mixture	1
Beet and other greens	8	Figs	1
Pears	7	Okra (and beans)	1
Peppers	4	Pickled tongue	1
Apricots	3	Pork	1
Chile con carne	3	Potatoes	1
Tuna	3	Pumpkin	1
Mushrooms	2	Smoked salmon	1
Salmon	2	Soy beans	1
Tomatoes	2	Soup mixture	1
Black-eyed beans	1	Vegetable salad	1
Carrots	1	Miscellaneous	4
Carrots and peas	1		
Cauliflower	1	Total	175

Although botulism is generally associated with low-acid foods, apricots, pears, figs, and tomatoes have been implicated in outbreaks. According to more recent information, the mold growth which may occur when these products are understerilized is capable of forming a favorable environment for the development and growth of *Cl. botulinum* and other organisms. As it grows, the mold may reduce the acidity in the jar, or in a portion of the jar, to the point where bacterial growth can take place.

Many of the case histories of botulism outbreaks show that the foods were canned by methods which are recognized as being inadequate. The so-called "open kettle" method of canning has been responsible for many outbreaks. The boiling water bath method of processing has probably been implicated more than any other. The outbreaks from foods canned in a pressure canner provide evidence that this piece of equipment may give a false sense of security unless it is operated correctly. And, as has been discussed previously, the failure of people to properly boil low-acid home-canned foods prior to tasting them might be given as a reason for most of the botulism outbreaks. Even if a food contained this toxin, it would be destroyed by boiling and in many cases an off odor would be given off which would indicate to the housewife that the food was unfit for consumption.

WHERE IS CLOSTRIDIUM BOTULINUM FOUND?

At least five different types or strains of *Cl. botulinum* are recognized at the present time:

Type A: A common soil anaerobe of the Western States, less frequently encountered in the Atlantic States, the Great Plains, the Mississippi Valley. Frequently associated with virgin mountain or forest soil but may be present in cultivated garden and field soils. Involved in many botulism outbreaks, particularly in the West. Produces a toxin of high potency.

Type B:	Capable of producing a toxin of high potency. According to some authors it is associated with manured soils and soils cultivated for a long time. Soils of Mississippi Valley, Great Lakes region, and Atlantic Coast States are characterized by a predominence of Type B. Associated with many outbreaks from home-canned foods.
Type C:	Reported to be cause of so-called "duck disease" and fowl "limberneck." Has not been associated with botulism outbreaks affecting humans.
Type D:	A relatively rare type. It is believed that the susceptibility of man to its toxin is low.
Type E:	Widely distributed but overlooked in the past. Isolated from Nova Scotia smoked salmon and German canned sprats. Cause of fatal cases of botulism in New York (Damon, 1928). Isolated from sturgeon and seal meat in Europe. It has not been associated with home-canned foods in the United States.

In 1922, Meyer, Dubovsky, Coleman and Schoenholz reported the results of a comprehensive survey on the distribution of the spores of *Cl. botulinum* in the United States. In this investigation 2,162 samples of soil and soil products were obtained from forty-seven states—from 1 to 624 samples from every state of the Union with the exception of Virginia. Approximately 26 percent of the specimens contained botulinum spores. A detailed study of the specimens according to their source (soil type) emphasized the predominance of *Cl. botulinum* in virgin and pasture soil. Earth contaminated with manure or animal excreta rarely carried the spores of this organism. On a basis of these data it was suggested that cultivation and cropping of the soil reduces or dilutes the number of spores to such a degree that the methods employed for detection failed to demonstrate their presence. The authors concluded that, while there is no doubt that every soil product may sometimes carry the spores of *Cl. botulinum* it is significant that string beans and leaves furnished the highest percentage of toxic and identified cultures. In this connection reference might be made to Table 2 which shows that string beans have been the most important cause of botulism outbreaks from home-canned foods.

It is also important to note that plant material undergoing decay and fermentation supplied a high percentage of toxic cultures and isolations of *Cl. botulinum.* The authors point out that this organism, being a spore-former, rarely meets in nature the conditions suitable for its growth. In soil, conditions favorable to growth probably occur when decaying vegetation furnishes the necessary food material. It is quite possible that the most heat-resistant spores do not occur on fresh and sound vegetables and fruits, but only on produce which is partly decayed or on that which has spoiled portions. With this in mind the recommendation that only fresh, sound vegetables be used in home canning assumes increased importance. On a basis of the survey discussed above the authors drew the following conclusions:

> 1. *Cl. botulinum* is a common soil anaerobe of the Western States of the Cordilleran system. It is less frequently encountered in the Atlantic States and is relatively rare in the Middle States, the Great Plains and the Mississippi Valley.

> 2. The soil of the Western States, inclusive of the Great Plains, yields, mainly *Cl. botulinum*, Type A, while the Mississippi and Great Lakes region is characterized by a striking predominance of Type B. Similarly prevalent is this latter type in the Atlantic States of Maryland, Delaware, New Jersey, Georgia, and South Carolina, while scattered findings of Type A in Maine, New York and Pennsylvania indicate the existence of breeding places in virgin forests and mountains. Soils which are subjected to intensive cultivation and fertilization contain, as a rule, *Cl. botulinum*, type B.
> 3. *Cl. botulinum* spores are far more prevalent in virgin and pasture soils than in dirt, soil or manure collected from animal corrals, pig pens, etc. Vegetables, fruits and feeds are frequently contaminated with the spores of this organism. String bean pods and leaves, moldy hay, ensilage and decayed vegetation may yield a relatively high percentage of positive cultures.
> 4. Human and animal botulism is not infrequent in those states in which *Cl. botulinum*, Type A, predominates, or in which the percentage figures of positive cultures exceeds 20 to 30 percent. From a practical standpoint, however, the organism is ubiquitous, and this survey gives no assurance that heat resistant spores cannot be found anywhere and at any time.

For an earlier soil survey, in California, Burke (1919) concluded that *Cl. botulinum* was widely distributed in nature. It is present in gardens and may be on fruit or vegetables when they are picked; it is not necessarily associated with active decay, but may be present in the blemishes or spots on the skin of apparently sound fruits and vegetables.

On the basis of a soil survey largely within the state of Illinois, Tanner and Dack (1922) concluded that *Cl. botulinum* is probably a common soil saprophyte widespread in nature.

The reported outbreaks of botulism from home-canned foods tend to follow the same geographical pattern as indicated by studies on the distribution of *Cl. botulinum* in soils. In Figure 1 the approximate geographical location of the botulism outbreaks described in Table 1 are indicated. This figure, while it shows the reported incidence of botulism to be confined to certain geographical areas, also indicates that the causative organism might well be expected to be found in other states, too. The number of botulism outbreaks from home-canned foods according to states is summarized in Table 3.

TABLE 3.—NUMBER OF OUTBREAKS OF BOTULISM FROM HOME-CANNED FOODS, ACCORDING TO STATES.

State	Number of Outbreaks	State	Number of Outbreaks	State	Number of Outbreaks
California	48	Wyoming	4	Kentucky	1
Washington	24	Ohio	3	Minnesota	1
Colorado	18	South Dakota	3	Oklahoma	1
Oregon	15	Tennessee	3	Utah	1
New York	10	New Jersey	2	West Virginia	1
Montana	9	Pennsylvania	2	Wisconsin	1
Nebraska	7	Texas	2	Connecticut	1(?)
Idaho	5	Arizona	1		——
New Mexico	5	Indiana	1		175
North Dakota	5	Iowa	1		

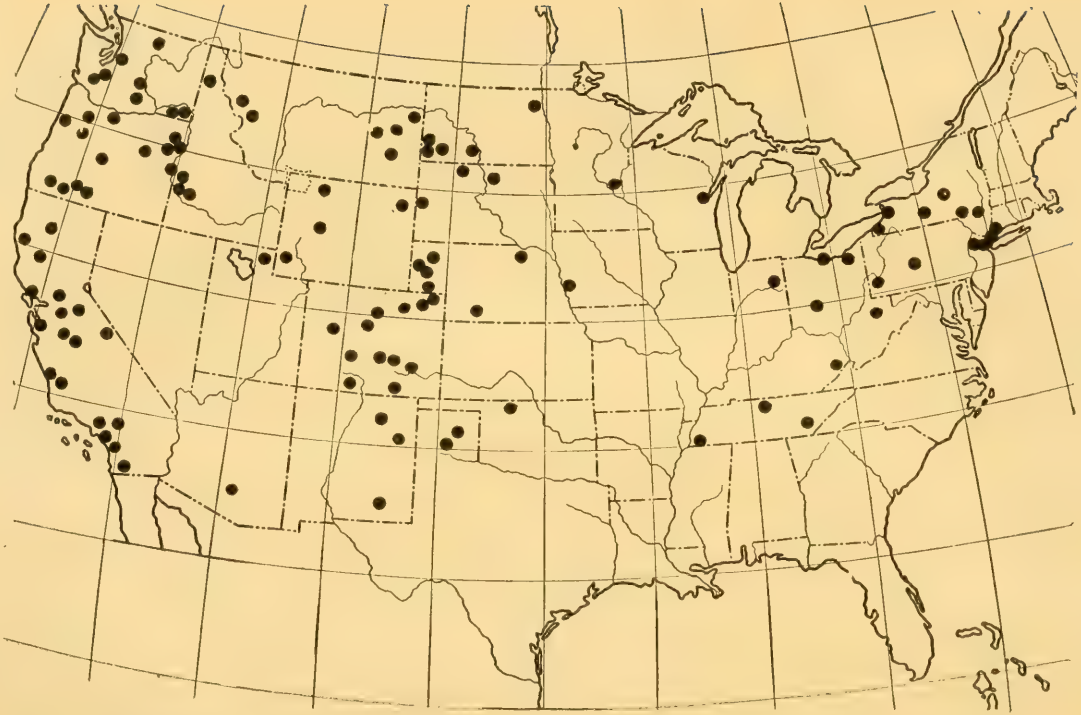


Figure 1. Geographical Location of Botulism Outbreaks from Home-Canned Foods in the United States. Each circle indicates area where one or more outbreaks have occurred.

PROPERTIES OF THE TOXIN PRODUCED BY CLOSTRIDIUM BOTULINUM

The toxin formed by *Cl. botulinum* is a true exotoxin; that is, it is excreted from the bacterial cell into the food where it remains unharmed for long periods. This potent toxin appears to be produced whenever abundant growth occurs, irrespective of the presence of fermentable carbohydrates. Jordan (1931) has described botulism toxin as follows:

> Botulism toxin differs from any other known bacterial toxin in that it is not destroyed by the gastric-intestinal secretions. It is extremely potent when tested either orally or parenterally, a culture filtrate subcutaneously injected frequently kills guinea pigs in a dose of 0.0001 cc.; when the filtrate is fed to guinea pigs 0.001 cc. often prove fatal. Briegen and Kempner obtained a toxin of which 0.000,001 cc. would kill a 250 gram guinea pig. *Cl. botulinum* may be likened to certain of the higher plants, such as poisonous mushrooms, the deadly night shade, and the fungus of ergot, which are dangerous by virtue of the poisonous compounds that are generated in their cells or in the substances which they proliferate.

Effect of Freezing

James (1933) has reported experiments in which botulinum toxin was frozen and defrosted 15 times without any reduction in strength. It would appear that this toxin is not affected by continued or intermittent freezing.

Effect of Heat

The toxin of *Cl. botulinum* is readily destroyed by heat. Thom (1922) pointed out that the temperature required to destroy this toxin varies considerably with the strain of the organism that is used, but that in every experiment reported, all trace of toxicity had disappeared in products actually heated throughout to 185°F. (85°C.), for a very few minutes. Tanner and Twohey (1926) concluded that (1) Under the conditions of the experiment the detoxification of the canned foods containing *Cl. botulinum* toxin required from 4 to 20 minutes heating at 212°F. (100°C.), (boiling water); from 25 to 45 minutes at 194°F. (90°C.); from 25 to 80 minutes at 176°F. (80°C.); from 45 to 75 minutes at 158°F. (70°C.); and longer than 4½ hours at 140°F. (60°C.). (2) The variation in the time required to destroy the toxin was explained on the basis of heat penetration into the product and variation in toxin content. Probably the same factors determine the destruction of toxin in canned foods that explain the destruction of bacteria during the canning process. (3) Heating of toxic foods to boiling under the usual conditions may not render them free from toxin. Suspicious foods, whether preserved by canning or other procedures, should not be eaten.

In 1943 the United States Department of Agriculture (1943) made the following recommendation for destroying botulinum toxin that might be present in home-canned foods.

> Home-canned non-acid vegetables processed by the boiling water bath method can contain botulinum toxin even if there are no signs of spoilage. To be safe, such products should be brought to a boil and boiled for at least ten minutes after the can or jar is emptied before they are eaten or even tasted. Boiling for a full ten minutes or more will destroy the toxin, though not the botulinum spores. It is the toxin, not the organism itself, that is harmful.

In California many technical studies have been made regarding botulism. This subject is of particular interest in that State because of the many outbreaks which have occurred there. The following recommendations were made in 1943 regarding the destruction of toxin in home-canned foods.

1. The California Department of Public Health (1943) advised that:

> Although the botulinus toxin is extremely poisonous, it is fairly readily destroyed by heat. The amount of heat required varies according to the food in question. To be on the safe side, *home canned vegetables, meat or fish, should always be brought to a boil and kept boiling at least* 15 *minutes before being used.* To ensure that all parts of the food are heated sufficiently *the food should be thoroughly stirred frequently during the heating period.* It should never be tasted before being heated, and should never be used cold in salads without first being boiled. With some products, particularly string beans, it is often very difficult to detect signs of spoilage when the jar is opened. On heating, however, the odor of decomposition is more apparent. Sometimes a very potent toxin may be present and yet the brine may be clear and there may be no off odor.

2. The California Extension Service (1943b) has advised the following heat treatments of home-canned foods in order to prevent botulism:

> a. If a non-acid food such as vegetables, meat, poultry, or fish has been processed in a pressure cooker with an accurate gauge or thermometer and if the method, pressure or temperature, and time prescribed have been followed, it should be unnecessary to reboil the canned product before using it. However, always boil string beans for 10 minutes before using them, even for salads.
>
> b. *Boil before tasting or using,* any such non-acid food canned without a pressure cooker or in a cooker with an untested gauge or thermometer, or if the prescribed processing or any part of the recommended method has not been followed.
>
> To boil, empty the food into a pan and place directly over the heat. Either cover the pan, or stir the food or break up clumps. *Count time after boiling has begun. Boil steadily for at least* 10 *minutes. Spinach and creamed corn must be boiled for at least* 20 *minutes.*
>
> c. *Never taste* any canned food having a disagreeable odor or showing gas pressure in the can, jar or bottle. A sour, rancid or putrid odor is a warning but may not be always present. The odor is intensified by boiling.

Effect of Acid

It has been reported that botulinum toxin is very resistant to acids (pH 4.0) but that it is less resistant to alkali. Bronfenbrenner and Schlesinger (1920) have reported that the toxicity of a crude filtrate or cultures of *Cl. botulinum* may be greatly increased by acidification (approximately pH. 4.0). Geiger (1923) pointed out that inasmuch as outbreaks of botulism have occurred following the consumption of vegetables, such as string beans and beets, served in the form of salads and containing vinegar, the definite knowledge of any increase in toxicity due to the addition of an acid might become of practical importance. However, in experimental work he found that the potency of the toxins of four strains of the organism was not increased by acidification. Bengtson (1924) reported a definite increase in toxicity upon acidification to pH 4.0. However, this increase in toxicity was not as great as that reported by Bronfenbrenner and Schlesinger (1920).

Effect of Other Agents

Tanner (1933) has pointed out that the recovery of certain persons from botulinum poisoning after eating toxic foods and drinking alcoholic beverages, suggested that ethyl alcohol has a destructive effect on the toxin. Several reports have been published which verify and confirm the fact that ethyl alcohol acts directly on the botulinum toxin. He raised the question, "Might this not explain the lower mortality from botulism in Germany, when alcoholic drinks are used more at meals, perhaps than in America?"

It has also been reported that this toxin may be destroyed by prolonged action of direct sun, diffuse daylight and air. Storing the toxin away from air maintained its toxicity for a longer time.

The effect of other bacteria on the toxin of *Cl. botulinum* is another factor which bears consideration. It is well known that one organism may destroy the toxin of another. Stark, Sherman and Stark (1929) found that in 14 days *B. subtilis* reduced the toxin titer of a botulinum filtrate from 300 M. L. D. to about 10 M. L. D. per cc. as determined by guinea pig inoculation. Jordan and Dack (1924) and Dack (1926) reported similar findings in the case of *Clostridium sporogenes*. Likewise other workers have found that several other common organisms exert an antagonistic affect toward botulinum toxin.

Botulinum Antitoxin

Geiger, Dickson and Meyer (1922) indicated that nothing definite can be said as to the value of antitoxin in the treatment of botulism, although it has been used in a number of cases. Experimental animals have been fully protected if sufficient antitoxin was given simultaneously with or a short time after the administration of the toxin. In their opinion the only conclusion that could be drawn was that botulinum antitoxin is of no value as a therapeutic agent when given late, after the onset of the poisoning. There were no records of its administration sufficiently early to provide any comparison with results obtained under experimental conditions. It was concluded that in all instances of botulinum intoxication the antitoxin should be administered as soon as possible after the consumption of the poisonous food. Tanner (1933) concluded that much work must yet be done if botulinum antitoxin is to assume a position equal to that of some of the other antitoxins.

WHAT FACTORS INFLUENCE THE GROWTH OF CLOSTRIDIUM BOTULINUM?

Growth in Foods

As may be seen in Table 2 many common foods permit growth and toxin formation by *Cl. botulinum*. Thompson and Tanner (1925) inoculated twenty-three kinds of food with detoxified spores of four strains of *Cl. botulinum*. Those found to be regularly toxic with all strains were red kidney beans, lima beans, hominy, peas, sweet potato, salmon, and shrimp. Those irregularly toxic were asparagus, beets, pumpkin, and spinach. The acid fruits and the very acid vegetable products, such as sauerkraut and dill pickle did not become toxic. They suggested that certain foods, such as spinach, asparagus, beets, and string beans, which have a natural acidity near pH 5.0 when a sound product is canned, have all the requirements for promoting good growth except that their acidity is on the border line. For this reason toxin production in cans of asparagus, string beans, beets, pumpkin, and spinach may occur irregularly. The acidity of certain canned vegetables was found to be greatly affected by the quality of the material put in the cans. Experiments with spinach showed that a small amount of rotted material would reduce the acidity to a point where *Cl. botulinum* could grow and develop a toxin. These results were in essential agreement with those reported earlier by Schoenholz, Esty and Meyer (1923). These latter authors also pointed out that the use of fresh and sound raw products, preferably obtained directly from the home garden and packed with the least delay, is one of the greatest means of protection against botulism.

As has been emphasized by many authors it is important to realize that frequently sufficient toxin to cause illness or death may be produced in canned foods before the appearance of the container or the appearance and odor of the food itself would give any warning of its dangerous nature.

Acidity

It is well known that acidity inhibits the growth and toxin production of *Cl. botulinum*. Attempts have been made to acidify low-acid foods so that they could be safely processed in a boiling water bath. Cruess (1932) believed that vegetables could be safely processed at 212°F. (100°C.) if the initial brine was so acidified that it would be at a pH of 4.5 or less after processing. Nehring and Bothe (1936) reported that it was wholly impractical, through the addition of acid to a vegetable conserve, to reduce the heat treatment. Savage and Hauwicke (1923) observed that the spores of *Cl. botulinum* were not likely to be killed by temperatures used in canning fruit, but if present would probably remain as such and not multiply.

In a study of the relationship of incubation temperature to viability, rate of growth, and toxin production of *Cl. botulinum* in different vegetables, Starin (1926) found that peas and corn showed decomposition. String beans and spinach exhibited little or no change in appearance or odor and the amount of toxin found was less than in the other two. This was thought to be due to the relatively high acidity of the string beans and spinach as compared with other so-called non-acid foods.

While acidification is used commercially, under carefully controlled conditions, to shorten the process time for certain low-acid foods, it is not a procedure to be generally recommended for home canning. In many cases, if sufficient acid were added to do the job intended, it would impart an off-flavor to the product. It is also difficult to control conditions in the home. For example, if vinegar were used as an acidulent, the directions would probably be based on ordinary 40 grain commercial vinegar. However, many homemade vinegars are less acid than this and their use would very likely lead to trouble.

Fong (1926) reported that vegetable brine must have a pH value below 5.0 to decrease the death time of bacteria at 212°F. (100°C.). A final pH value of 5.0 or greater produced no abnormal acid taste. Blanching with acid was effective in the destruction of bacteria during subsequent processing. When vegetables were processed for not less than one hour at 212°F. (100°C.), a safe pH value of the original brine for the prevention of spoilage by *Cl. sporogenes* and the thermophiles was about 3.0. *Cl. botulinum* required a pH value of 2.8.

Oxygen

Although *Cl. botulinum* is considered to be a strict anaerobe it seems to be able to tolerate a little oxygen. Dack, Starin and Werner (1927) stated that an oxygen pressure of 5 cm. completely inhibited this organism. Meyer (1929) reported that *Cl. parabotulinum Type A* and *Type B* failed to grow when the oxygen tension exceeded 1.14 cm. and 1.36 cm. or 7.16 and 8.6 percent, respectively. In another publication Dack and Baumgartner (1928) indicated that, when *Cl. botulinum* Type A was grown in veal infusion broth under reduced oxygen pressure, no growth was obtained when the pressure was greater than 1.3 cm. As the oxygen pressure increased from 0.1 cm. to 1.3 cm. the time of growth became more irregular.

Salt and Sugar

Experimental data reported by various research workers indicate that *Cl. botulinum* can tolerate relatively large concentrations of salt and sugar. Tanner (1933) has suggested that statements regarding the maximum concentration of salt tolerated by this organism are to be taken with considerable reservation, as the inhibiting concentration of sodium chloride seems to be influenced by the medium in which the experiments are carried out. In general a 10 percent concentration of salt would appear to inhibit the growth of the organism under most conditions.

Available reports indicate that sugar, except in high concentrations (greater than 55-64 percent), is not always effective in inhibiting the growth of *Cl. botulinum.*

Effect of Heating on Dormancy of Spores

Of particular interest in regard to home-canned foods is the effect of heating on the dormancy of the spores of *Cl. botulinum.* Dickson (1928) reported that spores which had been subjected to heat in a broth covered with a thin layer of oil within sealed glass tubes exhibited a marked dormancy. Positive tubes continued to appear from time to time for 75 months after the first tubes were heated and 67 months after the heating experiments were stopped. According to Burke (1923) spores which reproduce after long periods of dormancy are capable of producing typical and strong toxins.

Thus it would appear that home-canned foods may become toxic after long months of storage even though they were non-toxic for some time after canning. Warm storage conditions would tend to favor the development of dormant spores.

Temperature

Like other living things the spores of *Cl. botulinum* have an optimum temperature for growth and development. Although 71.6°F. (22°C.) has often been considered the optimum temperature for this organism, some data have been reported which show that growth and toxin production may occur at 98.6°F. (37°C.).

Tanner and Oglesby (1936) made a comprehensive survey of the literature on the effect of temperature on the growth of *Cl. botulinum.* Because little work had been done in the range of temperatures between freezing and room temperature

(32° to 68°F. or 0° to 20°C.), they carried on additional experimental studies in which it was found that, while all strains studied grew well and rapidly at 59°F. (15°C.), the spores of only three strains germinated at this temperature. Different strains varied materially in their temperature relations. It was concluded that foods may become dangerous fairly rapidly when stored at room temperature or under only slight refrigeration, but when kept at less than 50°F. (10°C.), they would remain safe for a considerable length of time.

It is obvious that low storage temperatures for home-canned foods are most desirable. This would hold true, as a guard not only against botulism, but also against other spoilage bacteria and as a means of better retaining the nutritive value, color, and flavor of all foods.

Effect of Other Microorganisms on Growth and Toxin Production by Clostridium botulinum

The presence and growth of other microorganisms in conjunction with *Cl. botulinum* frequently influence the growth and toxin production of the latter.

Jordan and Dack (1924) and Dack (1926) showed that *Cl. sporogenes* may prevent the development of *Cl. botulinum*, may diminish the amount of toxin that is produced, or may cause an early disappearance of the toxin. The growing cells of *Cl. sporogenes* destroyed the toxin of *Cl. botulinum*. Sommer and Glunz (1927) inoculated varying relative amounts of spore suspensions of *Cl. botulinum* and *Cl. sporogenes* into meat, spinach, and asparagus media. Botulinum toxin was formed in all of the meat cultures, irrespective of the presence of *Cl. sporogenes*. Toxin was produced in spinach only when the spores of *Cl. sporogenes* were exceeded in number by those of *Cl. botulinum*. In asparagus, a poorer medium for toxin formation, the presence of *Cl. sporogenes* had a greater inhibiting effect. In all three media, the strength of the toxin gradually diminished with increasing numbers of *Cl. sporogenes* spores. Stark, Sherman, and Stark (1929) found that *B. subtilis* reduced the toxin titer of botulinum filtrate. Kayukova and Kremer (1940) reported that *Cl. botulinum* did not grow in mixture with *Streptococcus thermophilus* and the toxin was gradually destroyed. *Bacillus mesenterious ruber* and *B. subtilis* activated the growth of *Cl. botulinum*, while *Clostridium putrificans* and *Cl. sporogenes* somewhat depressed toxin formation but did not destroy it.

It is particularly important to note that the presence of other microorganisms may favor toxin production under conditions which would otherwise repress it, such as in fruits and tomatoes. Bigelow and Cathcart (1921) believed that the formation of toxin in home-canned pears, responsible for a botulism outbreak, had been made possible by the growth of a yeast and a lactic acid producing bacterium. Edmondson, Giltner and Thom (1922) also reported that yeast growth favored toxin formation in foods. Outbreaks of botulism from home-canned tomatoes or fruit are believed to be due to the growth of mold in the product, which creates a favorable environment for the growth of *Cl. botulinum*.

According to Townsend (1943) mold growth reduces the acidity of acid foods and brings about a sufficient change in the protein to enable *Cl. botulinum* to grow. Because of this he advised that it was safest never to use any moldy canned fruit.

The above findings point to the fact that, if canned fruit and tomatoes are underprocessed to the extent that mold will grow in them, they may become potential sources of botulinum toxin. The process times recommended for such products are not severe enough to destroy the spores of *Cl. botulinum* if they are present because the acidity of the product is relied upon to prevent the growth of this organism.

HEAT RESISTANCE OF CLOSTRIDIUM BOTULINUM

Much work has been reported regarding the heat resistance of *Cl. botulinum*, particularly as it applies to commercial and home-canned foods. As a result of this work it has been definitely established that it is necessary to use a pressure canner, with processing temperatures of from 240°-250°F. (116°-121°C.) for processing home-canned low-acid foods in order to destroy the spores of this organism, as well as many other heat-resistant spoilage bacteria which may be present.

Esty and Meyer (1922) made a comprehensive study of the heat resistance of the spores of *Cl. botulinum* and their findings are still used as a basis for determining safe process times. They found that the maximum heat resistance of the spores of this organism, artificially produced under the most favorable conditions for growth and heated in a phosphate solution at pH 7.0, was as follows:

4 minutes at 248°F. (120°C.)
10 minutes at 239°F. (115°C.)
32 minutes at 230°F. (110°C.)
100 minutes at 221°F. (105°C.)
330 minutes at 212°F. (100°C.)

They pointed out that the heat resistance of spores of the same strain may vary considerably, depending upon several factors, some of which are unknown. The average resistance of the spores, as found in approximately 20 grams of either naturally or artificially contaminated soil, was less than three hours at 212°F. The heat resistance increased as the concentration of spores increased; that is, a longer process time would be required for a heavily contaminated product. The heat resistance of the spores in the juices of 17 varieties of canned food varied from less than 10 minutes to 230 minutes at 212°F. (100°C.).

In more recent studies to determine safe processes for canned foods, Townsend, Esty, and Baselt (1938) found that the heat resistance characteristics of *Cl. botulinum* in canned foods differed from those in neutral phosphate. The work of Esty and Meyer (1922) on this organism in neutral phosphate broth was well substantiated.

It is obvious from a study of available data that a boiling water bath process time long enough to destroy the spores of resistant strains of *Cl. botulinum* in a product would range from six to twelve hours and would be impractical. For this reason any one recommending boiling water bath process times should give consideration to the fact that such times as are recommended at present cannot be relied upon to destroy this organism.

ARE HOME CANNING PROCESS TIMES AS RECOMMENDED AT PRESENT ADEQUATE?

For some years the process times used in the canning industry have been based upon scientific determinations made through an application of studies of heat penetration and thermal death time. Although much is yet unknown regarding all factors which govern process times, much progress has been made in this field, largely through the efforts of the National Canners Association and the laboratories of several of the can manufacturers.

In view of the importance of home canning it is surprising that there has been but little effort to make a scientific study of the adequacy of home-canning process times. Cover, Turk and Kerns (1943) have applied some of the more recent technical methods of the study of process times for home-canned meats. They observed that the slow air cooling of glass containers in home canning allowed further sterilization to take place and pointed out that the method they used in calculating process times did not take this into consideration.

A research program designed to make a scientific study of home-canning process times was initiated by the Food Technology Department of the Massachusetts State College about two years ago. In this investigation methods developed by the National Canners Association Research Laboratory and associated laboratories are being applied to the determination and evaluation of home-canning process times. More recently a similar investigation has been started by the Bureau of Human Nutrition and Home Economics of the United States Department of agriculture.

Tischer and Esselen (1945) have summarized a preliminary investigation as follows:

> To obtain information on causes of spoilage in home-canned foods 293 jars of spoiled and sound home-canned foods put up in 1942 in Massachusetts by 270 families were collected. These families canned a total of 67,632 jars and reported an over-all spoilage of 1.96 percent. Approximately half of the jars received were spoiled and the remainder were considered to be sound. Each jar was examined bacteriologically and for physical defects. Of 133 spoiled jars 101 appeared to have been understerilized, 22 had been improperly sealed and 7 were apparently all right. Out of 146 "sound" jars 51 contained viable organisms which might cause spoilage under certain conditions. Four jars of tomatoes showed evidence of putrefactive spoilage, caused apparently by a preliminary growth of mold which created a favorable environment for the growth of a putrefactive anaerobe present in the product.
>
> Of 19 putrefactive anaerobes isolated from spoiled jars the spores of four, isolated respectively from asparagus, lima beans, and snap beans, survived heating for 30 minutes at 230°F. (110 C.). In phosphate buffer their "F" and "z" values were but slightly below those of Cameron's putrefactive anaerobe No. 3679. These organisms had a survival time of from 320 to 820 minutes at 212°F. (100°C.).
>
> As represented by this investigation it would appear that 80-85 percent of home canning spoilage is due to underprocessing and 15-20 percent to faulty sealing. The boiling water bath method of processing is not adequate to destroy certain types of bacteria encountered in home canning. While a pressure canner correctly used is satisfactory for processing, understerilization may result if it is mis-used.

In studies on the determination of process times for home-canned foods, Esselen and Tischer (1945) reported that theoretical process times for home-canned asparagus, beets, carrots, corn, snap beans, spinach, and squash were determined according to accepted methods, at processing temperatures of 212°F. (100°C.), 240°F. (116°C.), and 250°F. (121°C.). Process times based on the heat resistance of Cameron's putrefactive anaerobe No. 3679 were compared with those based on four heat-resistant putrefactive anaerobes isolated from home-canned foods.

The theoretical process times for vegetables processed in a pressure canner at 240°F. (116°C.) were found to be somewhat shorter than those recommended at present. Process times at 212°F. (100°C.) in a boiling water bath ranged from 5½ to 12 hours and serve to show that such process times as are recommended at present are inadequate to destroy certain types of bacteria encountered in home canning.

When the pressure canner is used, the relatively long come-up time plus the slow air-cooling period contribute significantly to the sterilizing value of the process. Eighteen to 35 percent of the sterilization occurs during cooling. In the case of the boiling water bath, 90-98 percent of the lethal value of the process must occur during the actual processing as the effect of the come-up and cooling periods is comparatively small.

The information obtained indicates that home-canning process times recommended at present may be more severe than are necessary and in many cases might be reduced. However, before any general recommendations are made, more experimental work must be done on home-canning process times and careful consideration given to the many variables encountered. Particular stress should be placed on the correct operation and maintenance of pressure canners in order to obtain the maximum sterilizing value from a given process.

Preliminary process times as determined by experimental methods for certain vegetables in pint jars are presented in Table 4.

TABLE 4. EXPERIMENTAL PROCESS TIMES AS DETERMINED FOR HOME CANNED VEGETABLE IN PINT JARS.

Vegetable	Required Process Time at 212°F. (100°C.)	Required Process Time at 240°F. (116°C.)	U.S.D.A. Process Time at 240°F. (116°C) Recommended in 1943
	Hours	*Minutes*	*Minutes*
Asparagus	10	25	35
Snap beans	10	22	30
Beets (sliced)	6¼	30	40
Carrots (sliced)	7¾	25	40
Corn (whole kernel)	12½	45	65
Peas	12	30	45
Spinach	10¼	65	95
Squash	over 6	75	85

The boiling water bath process times reported above are of equivalent sterilizing value to the process at 240°F. (116°C.), and are based on the time necessary to destroy the spores of *Cl. botulinum* and certain other heat-resistant spoilage organisms occasionally encountered in home canning. On the basis of these data it would appear that boiling water bath process times as recommended at present are inadequate to destroy the spores of all bacteria that are encountered in home canning and that might occasionally give trouble.

The experimental process times as listed above are not to be recommended at present because (1) *they must be checked further and* (2) *present methods of operating pressure canners leave much to be desired in many cases and a safety factor, as yet undetermined, must be added to those process times.*

WHAT ABOUT PRESSURE CANNERS?

So far as pressure canner operation is concerned, it has been found (Esselen, 1944) from experimental studies that many of the directions provided for home canning in pressure canners do not allow for sufficient venting and in some instances might contribute to underprocessing. A venting time of at least ten minutes is to be recommended for pressure canners of the size commonly used in home canning. It was further pointed out that if the actual temperature in a pressure canner was 235°F. (112.8°C.) because of insufficient venting, whereas the temperature shown by a pressure indicator was 240°F. (116°C.), the required process time should be considerably increased. In some cases the required process time at 235°F. (112.8°C.) would amount to as much as 140 percent of that at 240°F. (116°C.). Thus a product which required a process time of 30 minutes at 240°F. (116°C.) would have to be processed 42 minutes at 235°F. (112.8°C.) to receive the same degree of sterilization.

Inaccurate pressure gauges on pressure canners probably contribute to underprocessing in many cases. It is important that these gauges be tested at least once a year. Koon (1944) reported that, of 232 pressure canner pressure gauges tested at the Waltham Field Station, only 85 were accurate. The remainder registered from 1 to 7 pounds too low or too high. Many of the safety valves submitted were stuck and failed to blow off at pressures dangerous to the operator.

ATTITUDE OF UNITED STATES DEPARTMENT OF AGRICULTURE AND FOOD TECHNOLOGISTS TOWARD HOME CANNING AND BOTULISM

In 1928 Jordan and Falk (1928) summarized the situation in regard to home canning and botulism as follows:

> Since the spores of *Cl. botulinum* are relatively common in soil in many parts of the world and must adhere frequently to vegetables used for preservation, and since also the temperatures used in the home canning of food have in the past been often inadequate to insure complete sterilization, it might be expected that botulism would have occurred more commonly than has been the case. How can the rarity of the disease be explained? It is obvious that the factor necessary to bring about the production and persistence of botulism toxin in canned foods must occur relatively seldom. Numerous instances are on record in which the presence of botulinum toxin has been demonstrated in certain jars or cans of food while other jars or cans of the same lot preserved at the same time and to all appearances in the same manner have proved free of toxin. Among the factors that tend to prevent the production of botulinum toxin are an unsuitable reaction of the culture medium, the maintenance of an unsuitable temperature for germination, the presence of only a scanty number of uninjured spores, and the simultaneous presence of other organisms such as *Cl. sporogenes*. Even when once formed, the toxin of *Cl. botulinum* may sometimes be destroyed by the growth of *Cl. sporogenes*, and other anaerobes.

Without doubt the rarity of botulism and the apparent absence of outbreaks in certain sections of the country are due to some of the imponderables posed by Jordan.

In 1943 a press release from the United States Department of Agriculture stated:

> . . . . the use of the steam pressure canner is the only method it can recommend for the canning of certain types of vegetables. In response to numerous requests by individuals and agencies interested in the canning

> of Victory Garden Products, the Department made it clear that it can recommend only methods considered universally safe, since its published material is used in all parts of the United States. . . .
>
> In stating its recommendations, the Department of Agriculture made clear that *Bacillum botulinum* is widely distributed in soils, the number of cases of poisoning from home-canned non-acid foods is relatively small, and a large percentage of these reports have occurred on the Pacific Coast or in the Mountain and Great Plains States. Outside of these regions, some State Agricultural Colleges approve alternate methods of canning non-acid vegetables and meats, though all recommend the pressure canner as first choice. Each State College publishes directions for canning that it considers safe within its own State.

All food technologists who are familiar with the technical aspects of home canning and botulism are in agreement that only a pressure canner should be used for the processing of non-acid foods. The home-canning directions as provided by California clearly reflect the thinking of technical men toward this problem.

In the choice between recommending the boiling water bath method of canning or the use of a pressure canner the problem boils down to the question whether a method which is known to be satisfactory when correctly used is to be recommended, or whether one should assume the responsibility of recommending a method which might or might not be adequate. This is a matter which should be given considerable thought by agencies which supply recommendations for home canning, particularly when this information will be distributed all over the country. Although the incidence of botulism is very low, we are faced with a disease which, when it does strike, may kill an entire family.

Hall (1936) has quite aptly pointed out that those who assume the responsibility of providing the public with home-canning instructions are faced with the education of three distinct groups of housewives, as follows:

> 1. Those who are well grounded in the fundamental principles of bacteriology as applied to home canning; who intelligently use controlled steam pressure or intermittent sterilization methods of canning; who are ever conscious of the danger of botulism in spoiled canned foods; who never taste or serve spoiled food; and who always recook all canned foods before serving them. These housewives and their families rarely, if ever, die of botulism.
>
> 2. A very large number of women who have little or no knowledge of bacteriology; who use antiquated "cold pack" or other inadequate methods of canning, and who, having much spoilage, are vaguely conscious of an ill-defined element of danger which they attempt to avoid by tasting each jar of food before serving it. No doubt thousands of jars of perfectly harmless spoiled home-canned foods are discarded as a result of this common practice but from time to time a jar is encountered which contains botulinus toxin, resulting in the death of the human guinea-pig and often domestic fowls and other animals as well. In these cases the other members of the family do not suffer.
>
> 3. The third group consists of people who are at the bottom of the ladder educationally, socially and economically; who use the crudest methods of home canning; who seem to be oblivious of the danger of eating spoiled food; and who will apparently eat anything that looks like food if they can get it down. Such foods may be purposely fermented to impart a desired flavor, or they may be highly seasoned or flavored to mask spoilage. When botulism occurs under such conditions it usually takes a toll of several lives . . . .

SUMMARY

1. Its spectacular nature and high mortality give botulism a place out of proportion to its frequency as a cause of death.

2. Almost without exception botulism outbreaks are caused by carelessness and the use of faulty canning techniques. Water-bath processing and open-kettle canning are responsible for many outbreaks.

3. Home-canned string beans, corn, greens, asparagus, and beets are foods which have been largely responsible for botulism outbreaks. Many factors, some unknown, probably contribute to the low incidence of botulism from home-canned foods.

4. Botulinum organisms are widely distributed in nature and there is no evidence that they are confined to certain geographical areas.

5. The presence of decayed plant material favors the growth and development of the botulinum organism and for this reason the recommendation that only fresh sound products be used in home canning assumes an increased importance.

6. Botulinum toxin, if present in home-canned foods, may be destroyed by boiling the product for 10 to 20 minutes, depending upon the nature of the product.

7. Non-acid foods canned without a pressure canner or in a pressure canner incorrectly used *should never be tasted before they are boiled.*

8. Never taste any canned foods having a disagreeable odor or showing evidence of spoilage.

9. The addition of an acid, such as vinegar, to home-canned foods which contain botulinum toxin may increase the potency of the toxin. This may have a practical significance when such products as string beans are used for salads without being heated after the jar is opened.

10. Little is known regarding the effectiveness of botulinum antitoxin so far as human cases are concerned. Available evidence would indicate that it is effective if administered soon after consumption of the toxic foods.

11. *Cl. botulinum* can grow in many of the foods commonly canned at home. Frequently sufficient toxin to cause illness or death may be produced in canned foods before the appearance of the container or the food gives any warning of its dangerous nature.

12. The acidification of home-canned foods in order to reduce required process times is not generally recommended.

13. A toxin may develop in home-canned foods even after long months of storage. It is recommended that home-canned foods be stored at a low temperature in order to retard or prevent the growth of viable organisms which might be present in the jar.

14. In some instances other spoilage bacteria may grow in jars of underprocessed food and inhibit or retard growth and toxin formation by *Cl. botulinum.* In many such cases the food would be obviously spoiled from appearance and would not be eaten.

15. Botulinum toxin may be produced in canned fruits and tomatoes if a mold or yeast growth occurs which provides a favorable environment for the development of *Cl. botulinum.* Such products, when moldy, should not be eaten.

16. Some spores of *Cl. botulinum* are very heat resistant and practical boiling water bath process times are inadequate to destroy them. Six to twelve hours in a boiling water bath would be necessary to give the same degree of sterilization as the recommended process times at 240°F. (116°C.).

17. Experimental data indicate that many 240°F. (116°C.) process times for vegetables as recommended at present are more severe than necessary and can be reduced, with a resulting improvement in the quality of the canned products, when additional information is available and home-canning techniques are improved.

18. It is important that pressure canners be kept in good operating condition and be correctly used. Otherwise understerilization may result.

LITERATURE CITED

Bengtson, J. A., U. S. Pub. Health Serv., Hyg. Lab. Bul. 136, 101 p. (1924).

Bigelow, W. D., and Cathcart, P. H., Natl. Canners Assoc. Bul. 17L, 46 p. (1921).

Bronfenbrenner, J., and Schlesinger, M. J., Soc. Expt. Biol. and Med. Proc. 18:304-305 (1920).

Burke, G. S., J. Bact. 4:541-553 (1919).

Burke, G. S., J. Infect. Dis. 32:433-438 (1923).

California State Department of Public Health, Spoilage in canned foods and its prevention. 8 p. (1943).

California Extension Service, Home canning disaster file (1943a).

California Extension Service, Home Canning, by Hilda Faust, 8 p. (1943b).

Cover, S., Turk, R. D., and Kerns, A. H., Texas Agr. Expt. Sta. Bul. 635, 21 p. (1943).

Cruess, W. V., Food Manuf. 7:115-119 (1932).

Dack, G. M., J. Infect. Dis. 38:165-173 (1926).

Dack, G. M., Starin, W. A., and Werner, M., J. Infect. Dis. 40:525-532 (1927).

Dack, G. M., and Baumgartner, M., J. Infect. Dis. 42:491-494 (1928).

Damon, S. R., Food Infection and Food Intoxication. The Williams and Wilkins Co., Baltimore, Md. 266 p. (1928).

Dickson, E. C., Soc. Expt. Biol. and Med. Proc. 25:426-427 (1928).

Edmondson, R. B., Giltner, L. T., and Thom, C., Abs. Bact. 6:23 (1922).

Esselen, W. B., Jr., J. Home Econ. 36:143-146 (1944).

Esselen, W. B., Jr., and Tischer, R. G., Abst. of paper reported at May 1944 meeting, Soc. Am. Bact. In press, Food Res. (1945).

Esty, J. R., and Meyer, K. F., J. Infect. Dis. 31:650-663 (1922).

Fong, W. Y., Am. Food J. 21:204-207 (1926).

Geiger, J. C., U. S. Pub. Health Serv. Repts. 38:(39), 2249-2252 (1923).

Geiger, J. C., Dickson,, E. C., and Meyer, K. F., U. S. Pub. Health Serv. Bul. 127, 119 p. (1922).

Hall, I. C., Food Res. 1:171-198 (1936).

Hazen, E. L., Health News, N. Y. State Dept. Health 15: (39), 162 (1938).

Hicks, C. A., New Rochelle, N. Y., Health Department. Personal communication (1944).

James, L. H., J. Infect. Dis. 52:236-241 (1933).

Jordan, E. O., General Bacteriology. W. B. Saunders Co., Philadelphia, Pa. 819 p. (1931).

Jordan, E. O., and Dack, G. M., J. Infect. Dis. 35:576-580 (1924).

Jordan, E. O., and Falk, I. S., The Newer Knowledge of Bacteriology and Immunology. Univ. of Chicago Press, Chicago, Ill. 1196 p. (1928).

Kayukova, N. I., and Kremer, T. A., Microbiology (U.S.S.R.) 9:585-593 (1940). (C. A. 35:4057, 1941).

Koon, R. M., Mass. Agr. Expt. Sta. Bul. 417 (Ann. Rept.):71 (1944).

Meyer, K. F., J. Infect. Dis. 44:408-411 (1929).

Meyer, K. F., Personal communication (1943).

Meyer, K. F., Dubovsky, B. J., Coleman, G. E., and Schoenholz, P., J. Infect. Dis. 31:501-616 (1922).

Nehring, E., and Bothe, F., Ztschr. f. Untersuch. der Lebensmtl. 71:44-57 (1936).

Savage, W. G., and Hauwicke, R. F., Dept. Sci. and Ind. Res. Food Invest. Board, Spec. Rept. No. 16, 34 p. (1923).

Schoenholz, P., Esty, J. R., and Meyer, K. F., J. Infect. Dis. 33:289-327 (1923).

Sommer, E. W., and Glunz, K., J. Infect. Dis. 41:442-447 (1927).

Starin, W. A., J. Infect. Dis. 38:106-114 (1926).

Stark, C. N., Sherman, J. M., and Stark, P., Soc. Expt. Biol. and Med. Proc. 26:343-344 (1929).

Tanner, F. W., Food-Borne Infections and Intoxications. The Twin City Publishing Co., Champaign, Ill. 439 p. (1933).

Tanner, F. W., J. Home Econ. 26:365-376 (1934).

Tanner, F. W., and Dack, G. M., J. Infect. Dis. 31:92-100 (1922).

Tanner, F. W., and Oglesby, E. W., Food Res. 1:481-494 (1936).

Tanner, F. W., and Twohey, H. B., Zentbl. f. Bakt. [etc.] 98:136-141 (1926).

Thom, C., Am. J. Pub. Health 12:49-53 (1922).

Thompson, L. and Tanner, F. W., J. Infect. Dis. 37:344-352 (1925).

Tischer, R. G., and Esselen, W. B., Jr., Abst. of paper reported at May 1944 meeting, Soc. Am. Bact. In press Food Res. (1945).

Townsend, C. T., Proc. Meeting on Spoilage Problems in Home Preserved Foods, Univ. of California, November 13, 1942. 67 p. (1943).

Townsend, C. T., Esty, J. R., and Baselt, F. C., Food Res. 3:323-346 (1938).

United States Department of Agriculture, Press Release, April 7 (1943).

PUBLICATION OF THIS DOCUMENT APPROVED BY COMMISSION ON ADMINISTRATION AND FINANCE
5M-5-45-16229

JAN 25 194